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(4) POWER-LINE COMMUNICATION APPARATUS.

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De cription

Related Application

This application is a continuation-in-part of U.S. Serial No. 429,208 filed October 30, 1989 which is itself a continuation-in-part of U.S. Serial No. 344,907, filed April 28, 1989.

Background of the invention

1. Field of the Invention

The present invention is related generally to power system communications, and more particularly to apparatus capable of simultaneously transmitting and receiving digital data signals both at high rates and over long distances through power-lines and through power line transformers, including AC, DC and coaxial cables (including phone lines).

2. Statement of the Prior Art

"Power-line carriers" are well known in the field of power system communications. The principal elements of such power-line carriers are transmitting and receiving terminals, which include one or more line traps, one or more coupling capacitors, as well as tuning and coupling equipment. Detailed information tegarding the description and typical composition of conventional power-line carriers may be found in Fundamentals Handbook of Electrical and Computer Engineering, Volume II: Communication, Control, Devicas, and Systems, John Wiley & Sons, 1983, pp. 617-627. TK151.F86, the contents of which are incorporated herein by reference.

A power line communication ayatem is generally known from EP-A-0 115 814 A1. This system is characterized by a signal transmitter cooperating with a three-phase power line by means of a circuit including a transformer unit and capacitors functioning as a coupler means.

A significant problem associated with such prior art power-line carriers is their requirement for one or more coupling capacitors, one or more coupling transformers or one or more carrier or more coupling transformers or one or more carrier frequency hybrid circuits and frequency connection cable. Furthermore, in traditional systems the modulation at the transmitter and receivers is not synchronized. Traditional systems experience distance limitations whenever AM or FM demodulation is used, and they pick up the 60 Hz signal and its harmonics from the power-linees. To the extent that the carrier frequency is received at all, it is often too weak to demodulate. Such systems further have a narrow bandmodulate. Such systems further have a narrow bandmodulate. Such systems further have a narrow bandmodulate. Such systems further have a narrow bandmodulate.

carrier frequency.

One prior art method operates at a frequency of

betwe n betwe n 20KHz and 400Khz where th att nustion of the power lin is greater. How ver, the 60Hz harmonics are still picked up by such a system. Accordingly, th re is still a n ed to use high power transmission b caus of noise and coupling losses of greater than 20dB. As a result, the signals must be transmitted over the power-lines at very high power

Still other prior art methods operate below 20 KHz where the attenuation of the power-lines is lower. However, such systems experience a high level of noise and a very small bandwidth. These systems also experience at least a 20dB loss through the coupler.

outputs and low bandwidths.

All existing systems attempt to communicate between the harmonics rather than by reducing the
noise significantly through the coupler. In addition,
prior art systems are location dependent and are atfected by their relative position with respect to transformers or other plugged in equipment. Frequently,
prior art power line communication mechanisms must
perform a frequency transponent in both the transmitter and receiver, thus requiring two or more quartz
oscillators.

Finally, all previous power line communication of systems are characterized by their incorporation of magnetic or ferrite (iron) core linear transformers for both transmission and reception in the duplexing system. Because these systems are magnetically coupled, and the 60Hz current is greater than zero, they pass a significant amount of the 60Hz high power signals and its resulting harmonmics.

a 20 (decebel) dB power loss over their associated systems. Thus, such systems frequently experience resonate with the coupling capacitors used with such Further, systems using magnetic transformers do not quires high power transmission of the carrier signal. current passed to the transmitter, it consequently rewindings to 10:1. While this results in a smaller "back" been to increase the ratio of the primary to secondary ventional response to this particular problem has currents which can damage the transmitter. The conpass back large percentages of the 60Hz power-line pled transformers. Magnetic transformers tend to formers and devices incorporating magnetically counetic transformers are affected by distribution transsion is itself a cause of several problems. First, mag-The use of magnetic transformers for transmis-

The problems associated with the use of magnetic transformers in receivers are equally significant. The use of magnetic linear transforms require the use of filters which pass a narrow bandwidth. As a result, prior art systems are slow (maximum of 100 baud). The transformer further picks up the magnetic field for every frequency and accordingly picks up the 60Hz signal and its harmonics. This further exacerbates the need for filtering in the receiver. In addition,

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coupling capacitor.

p rmit high sp ed, high band power lin communication at frequ ncies up to 1 MHz (with less than about a 200 KHZ bandwidth) for applications including LAM (local area networks) and phone line communication at frequencies up to 160 KHz with about a 20 KHZ bandwidth for high distance, high voltage and LAM communications; and communication at frequencies up to 35 KHz (preferably 7-15KHz) with about a 6 KHz bandwidth for communication with about a 6 KHz bandwidth for communication air coil transformers of the present invention are equally applicable to any high voltage DC communication are cations preferably up to 160 KHz.

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In view of the above, it is an object of the present invention to provide a power line communications apparatus which utilizes novel non-linear transformers

for both transmission and reception.

It is a further object of the present invention to provide power line communication apparatus utilizing

provide power line communication apparatus utilizing novel air coil transformers which can be used for phone line, coaxial, LAN, power line and power line communication through power line transformers.

It is an additional object of the present invention to provide a power line communication apparatus in which the primary coil of the transformer resonates with an associated coupling capacitor network in order to maximize the transmission and reception voltages at the respective carrier frequencies. This resonation effectively creates a band pass filter at carrier frequency.

It is still a further object of the present invention to provide a communications apparatus in which a non-linear transmission transformer has primary and secondary windings in which the ratio of the windings is about 1:1.

It is still yet a further object of the present invention to provide a communications apparatus in which the receiver coupling contains a capacitor network which impedes the 60Hz high power signal and its harmonics.

It is still yet a further object of the present invention to provide a communications apparatus in which the receiving network includes a non-linear air coil transformer in which the ratio of the primary to sectoansty windings is about 1:1.

It is still yet a further object of the present invention to provide a communications apparatus in which the capacitor network for both transmission and reception include resistors which divide down the AC voltage evenly. The resistors also serve to protect the system against spiking and lightning.

It is still yet a further object of the present invention to provide a communications apparatus which can provide a high bandwidth for the transmission of communications signals at speeds greater than 9600 band, and at speeds of up to 1200 band directly

through power line transformers.
It is yet a further object of the present invention

th impedanc of the primary of th magnetic transformer will b effected by the a condary sid of the transformer which will not allow good matching conditions to the power line. This can result in mistuning which can be further aggravated by other power line transformers.

Prior art power line communications aystems are also typically loud and require expensive repeaters which require at least 600 watts of power for transmission.

Prior art methods of telephone line communication also use magnetically coupled transformers which have similar narrow bandwidths and noise problems. The impedances of such systems do not match the impedance of the phone line well.

Figures 1-3 schematically illustrate the problems associated with prior art magnetic linear transformers as applied in power line communications systems. As can particularly be seen in Figure 3, such systems produce a narrow bandwidth and do not adequately attenuate the low frequency power signal and its harmonics.

power line. from a systematic standpoint, function as part of the perience gain for reception and transmission, and non-linear transformers of the present invention extransformers characteristic of prior art systems, the low power transmission. In contrast to magnetic power line transformers over long distances and at ent invention permit communication directly through frequencies. The novel air coil transformers the pressignal for better transmission and reception of carrier which thereby simultaneously maximize the carrier mize the 60Hz power signal and its harmonics, and spective resonating capacitor networks which miniitively coupled air coil transformers coupled with re-The present invention incorporates non-linear capacis directed to solving the above-mentioned problems. The present invention, characterized by Figure 4,

communications over great distances. spove factors work to produce high speed power line cause attenuation is equal in both directions. All of the mera are irrelevant using this coupling technique, bestep-up or step-down aspects of power-line transforwhich will be a function of part of the power line. The the resistivity of the primary air coil to the power line, quently, impedance matching can be achieved using effect from other power line transformers. Consethe secondary side-of the air coil and no impedance coil transformers creates no impedance effect from jority of the harmonics are eliminated. The use of air transformer passes none of the 60Hz signal, the ma-60Hz power line signal and because the nonlinear system noise is generated by the harmonics of the frequencies for which they are designed. Because tion are capacitively coupled and will only pick up the The non-linear transformers of the present inver-

The air ∞ il transformers of the present invention

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"SBU! lines, coaxial lines and any high voltage DC power plications include data transmission through phone printers at sp. eds in xcess of 9600 baud. Other apb n used to transmit data between computers and min s. The apparatus of the present invention has

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drawings wherein: considered in conjunction with the accompanying from the following detailed description thereof, when the present invention will become more apparent Other objects, advantages, and novel features of

Brief Description of the Drawings

duplexing couplers on both low and high voltage pow-Figs. 1 and 2 schematically represent traditional

Fig. 3 illustrates the frequency characteristics of er lines.

Fig. 4 schematically represents the LC coupler of traditional serial LC couplers.

Fig. 5 illustrates the frequency characteristics of the present invention.

Fig. 6 is a block diagram of a power-line commuthe LC coupler of the present invention.

vention; nication apparatus in accordance with the present in-

nication apparatus in accordance with the present in-Fig. 6A is a block diagram of a power-line commu-

which corresponds to the coupling TA-RB shown in means in accordance with the present invention, Fig. 7 is a schematic diagram of first coupling vention including power-line transformers;

which corresponds to the coupling TB-RA shown in means in accordance with the present invention, Fig. 8 is a schematic diagram of second coupling Figs. 6 and 6A;

Figs. 9A and 9B illustrate the non-linear transfor-Figs. 6 and 6A;

cordance with the present invention for data commu-Fig. 9C illustrates a half duplexing coupler in acmer air coils utilized in the present invention.

modulator FA/demodulator FB for the system in Fig. Fig. 10B is a schematic diagram of an alternative the modulator FA/demodulator FB shown in Figure 6. Fig. 10A is a schematic diagram corresponding to nications through distribution transformers.

which can function as the modulator/demodulator cir-Fig. 10C is an FSK decoder phase lock loop .6

cuit of Fig. 6;

;A01 Fig. 10D is the primary phase lock loop of Fig.

means used in the present invention; Fig. 11 is a schematic diagram of a transmitter

data signals over long distances. shown in Fig. 11, in the power-line communication of used in conjunction with the transmitter means Fig. 12 is a schematic diagram of receiver means

> It is still yet a further object of the present invensmall coupling capacitance between the solenoids. diam t re thus defining an air gap, which creates a two single layer finite sol noids each having different non-linear air coil transformer effectiv ly comprising to provide a communications apparatus containing a

tion to provide apparatus for power system commu-

nications over long distances.

ear transformer have different diameters. which the primary and secondary coils of the non-linparatus to provide power line communications in It is still yet an additional object of the present ap-

mary side of the non-linear transformer. in which coupling especitor resonates with the priprovide an apparatus for power line communications It is yet another object of the present invention to

communications. pled with a capacitor network for use in telephone line to provide a novel non-linear air coil transformer cou-It is still a further object of the present invention

Summary of the Invention

cording to claim 1. ratus for power-line communications is disclosed ac-In accordance with the present invention, appa-

pass filter. ings, with the coupling capacitance, function as a high capacitance through the air gap, the secondary wind-(which function as solenoids) create a small coupling least 80dB attenuation. Because the air windings which cut the 60Hz harmonics below 10KHz with at works) as the non-linear transformer (high pass filter) air windings function (with resonating capacitor netinvention, air coils comprising primary and secondary In accordance with a major aspect of the present

through the phone sytem. tage power-lines using addressable data transmitted curity systems in homes could be set up over high voldition, public phone systems in trains and internal se-(13,800, 22,000, 69,000 voltage power-lines). In adand directly through the distribution transformer house (120/240/480 Volts), to the distribution line, with addressable data using two frequencies from system, such readings could be made by a computer through power line transformers. In a hypothetical high data rates, over long distances and directly Such readings can be transmitted at low power, at over power-lines for large numbers of customers. sible to transmit electricity and gas meter readings way of example, the present invention makes it posnications between computers over power-lines. By switching of remote control devices, and data commucations are in electricity and gas meter readings, the vention has numerous applications. The main appli-The communications apparatus of the present in-

control large or small machines in factories and The present invention can be further utilized to

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means 23. modulator m ans 28 comprise a second modem t r means 24, receiver means 26 and modulator/ded modulator m and 28. Th combination of transmit-

to function as a simple receiver or transmitter. nications apparatus, either circuit may be configured ing described in the context of two identical commu-It is to be noted that while the present invention is beinductive (L) component of the respective LC circuits. both transmission and reception which serve as the corporates novel non-linear aircoil transformers for See Figure 4. The coupling means 14, 22 further inare connected in a series and parallel configuration. The LC circuits include a plurality of capacitors which pling means 14, 22 resonate at a given frequency. of the serial LC circuits in a respective one of the couratus is coupled to power-line transformers 27. Each pair of power-lines 12. Referring to Fig. 6A, the appaial LC circuits (Figs. 7 and 8) which are coupled to the low, both coupling means 14, 22 include a pair of ser--ed niered listeb ater detail herein be-

by the second carrier frequency FB. FA, and demodulates the digital data signals carried data signals to be carried by the first carrier frequency and the first receiver means 18, modulates the digital 20, coupled between the first transmitter means 16 power-lines 12. The modulator/demodulator means by a second carrier frequency FB from the pair of 14, is capable of receiving digital data signals carried ceiver means 18, coupled to the first coupling means Fig. 6A, through power line transformers. The first re-FA across the pair of power-lines 12, and as shown in digital data signals carried by a first carrier frequency first coupling means 14, is capable of transmitting The first transmitter means 16, coupled to the

the first carrier frequency FA. and demodulates the digital data signals carried by nals to be carried by the second carrier frequency FB ond receiver means 26, modulates the digital data sigtween the second transmitter means 24 and the sec-The second modulator/demodulator 28, coupled becarrier frequency FA from the pair of power-lines 12. receiving the digital data signals carried by the first to said second coupling means 22, and is capable of Accordingly, the second receiver means 26 is coupled as shown in Fig. 6A, through power-line transformers. frequency FB across the pair of power-lines 12, and digital data signals to be carried by the second carrier transmitter means 24 is capable of transmitting the is coupled to the second coupling means 22. Second the power-lines 12, the second transmitter means 24 In a similar manner, at the second location along

30 kilohertz. For most high voltage, long distance coupling means 14, 22 preferably comprises less than any other frequencies. The bandwidth of each of the hertz), at a power level of about 20 decibels above preferably comprise frequencies up to 1MHz (mega-The first and second carrier frequencies FA, FB

> Fig. 14 is a sch matic representation of a thre pling for the power line from phase to ground. Fig. 13 is a sch matic representation of a coucan be us d for high spe d communications. Fig. 12A is a sch mattic diagram of a reciv rwhich

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ground. phase coupling to the powerline, three phases to

Fig. 15 illustrates a two phase coupling connec-

Fig. 16 shown a three phase transformer coution-to the power line, phase to phase.

Fig. 17 shows a one phase transformer coupling pling of the type predominantly used in Europe.

Fig. 18 shows a spread spectrum transmitter/reof the type generally used in the United States.

tween noise. is particularly applicable for communication in beceiver in accordance with the present invention which

which can be utilized with the present invention. Fig. 19 Bi-Polar Shift Keying transmitter/receiver

underground power line with the power line impe-Fig. 20 is an equivalent circuit of the upper and

KM distance. carrier frequency on the 35 KVAC power line for a 20 Fig. 21 is a graph of power line attenuation versus

of the present invention which may be implement by ing system incorporating the communication system Fig. 22 is an illustration of an electric meter read-

MAL is nithiw noitnewni theserg ent to erelguobe eth Fig. 22A is a block diagram illustrating the use of

22 as applied to a multiplicity of substations. Fig. 23 is a block diagram of the system of Figure linked by power lines or conventional phone lines.

Fig. 24 is a simplified block diagram of the system

Fig. 25 is a block diagram of a power line commuof Fig. SZ.

Detailed Description of the Invention

nication system.

qsuces.

for use in low power applications (up to 480 VAC). tion apparatus 10 according to the present invention 6 and 6A block diagrams of a power-line communicaout each of the several views, there is shown in Figs. bers designate like or corresponding parts through-Referring now to the Figures, wherein like num-

second receiver means 26, and second modulatorcoupling means 22, second transmitter means 24, At a second location along power-line 12 are second ulator means 20 comprise a first modern means 21. means 16, receiver means 18 and modulator/demodpower-lines 12. The combination of transmitter tor/demodulator means 20 at a first location along the means 16, first receiver means 18, and first modulaprises first coupling means 14, first transmitter pled to a pair of power-lines 12, and generally com-The communications apparatus 10 shown is cou-

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together in parall I between one of the power-lines 12 and the primary winding 38 of the first air coil 36. The primary winding 38 of the first air coil 36 is thereafter serondary winding 40 of the first air coil 36 is consected to its respective transmitter means 16. The nected to its respective transmitter means 16. The second plurality of capacitors 42 are serially connected to its respective of power-lines 12 and the primary winding 46 of the second air coil 44. The primary winding 46 of the second air coil 44. The pribeing serially connected to the other power-line 12. As noted above resistors, 35 and 45 function to evenly divide the voltage and serve to minimize spiking and afford lightning protection.

current at the carrier frequency FA. filter at the carrier frequency FA. This maximizes the at the carrier frequency FA, thus creating a band pass ther Ceat is set to resonate with the primary winding thereby achieving a gain on the secondary side. Furart devices. The primary coil resonates with Ceqt, high transmission voltage, as is characterized by prior ratio. Accordingly, the transmitter doesn't require a furns (designated by $M_1 = M_2$), and are thus at a 1:1 in the transmitter air coils have the same numbers of that both the primary and secondary windings 38, 40 tween the two. Of particular significance is the fact winding 2r 41 and accordingly creates an air gap bewhich is greater than the diameter of the secondary The primary winding 38 has a winding diameter 2R 39 ing 40 which is placed between the primary winding. mary winding 38 and coaxial smaller secondary wind-The transformer is non-linear and comprises a priconnected in series with Ceqt and the power line 12. shown in Fig. 9A, the transmitter transformer 36 is former 36 with coupling capacitor network Ceat. As reception. Figure 9A illustrates the transmitter transpled air coil transformers for both transmission and function as respective non-linear capacitively coubed in greater detail. The novel air coil structures transformers used in the present invention are descri-Referring to Figs. 9A-9C, the non-linear air coil

The values of C_{eq1} and the resistors 35, 45 are set to generate a large voltage loss at frequencies less that 10KHz (thus encompassing the 60Hz power line signal). Thus, the significantly reduced 60Hz signal cannot generate a large enough current to pass the created small capacitance. That is, for transmission, the resistivity of the primary coil is roughly equal to the input impedance of the power line.

The receiver transformer is now described with respect to Fig. 9B. The receiver is connected to the power line 12 via C_{oq2}. As with the transmitter of Figure 9A, the receiver air coil comprises a non-linear transformer having a primary winding 46 with a first diameter 2R 47 and a secondary coaxial winding 48 having a second diameter 2r 49. Accordingly, an air paying a second diameter 2r 49. Accordingly, an air paying a second diameter 2r 49. Accordingly, an air as the tespective primary and secondary ated between the respective primary and secondary

communications, the first and second carrier frequencies FA, FB will typically comprise frequencies that are less than 20 KHz. When used for communication of less than 20 KHz. When used for communication through power line transformers, FA and FB will typically comprise frequencies below 35 KHz (preferably 7-15 KHz) with bandwidths of about 6 KHz. The serial LC circuits (Figs. 7 and 8) of both coupling means 14, 22 each comprise impedance matching means 44, will be described in greater detail below.

With reference next to Figs. 7 and 8, the specific circuitry for representative coupling means 14, 22 is now described in greater detail. The coupling means 14 (Fig. 7), 22 (Fig. 8) each include a pair of serial LC circuits 30, 32 which resonate at the carrier frequencies FA, FB. It will be appreciated by those skilled in the art that for FSK (Frequency Shift Key) applications FA will correspond to F₁ and F₂ and FB will correspond to F₂ and FB will correspond to F₃ and F₄. The serial LC circuit 30 shown in Fig. 7 resonates at the second carrier frequency FA while serial LC circuit 32 resonates at the first carrier frequency FA. Similarly, the serial LC circuit 30 of Fig. 8 resonates-at the first carrier frequency FA. Similarly, and serial LC circuit 32 resonates at the second carrier fig. 8 resonates-at the first carrier frequency FA, and serial LC circuit 32 resonates at the second carrier frequency FB.

ning protection. DC current so as to prevent spiking and afford light-The use of the resistors 35, 45 serve to minimize the lator and the air coil transformer placed into a resin. itors should be separately placed in an oil filled insu-22 KV. At operating voltages above 22 KV, the capacsulation when used with operating voltages up to to plers (LC) should be placed into a resin for good initors should similarly be high. In operation, the couthick film (i.e. carbonless). The Q point of the capac-VAC capacitors. The resistors should preferably be ohm per 5 watts and the capacitors should be 200 ably, the resistor values should be rated at 1 Megawhich evenly divides down the AC voltage. Prefereach capacitor in series is connected a resistor 35, 45 parallely connected capacitor networks 34, 42. To The LC circuits include respective serially and

It is to be appreciated that the capacitor networks 34, 42 create equivalent capacitances $C_{(eq1)}$ and $C_{(eq2)}$ for transmission and reception, respectively. The capacitor networks are connected to non-linear air coil transformers to be discussed below which function as the inductive element (L) of the LC circuit. $C_{(eq1)}$ and $C_{(eq2)}$ resonate with the primary windings of the non-linear transformers.

The sir coil means comprise a first sir coil 36 which includes a primary winding 38 and a smaller secondary, winding 40 situated coaxially within the primary winding. The second serior a primary winding 46 and smaller secondary winding 48 situated coaxially within the primary winding.

The first plurality of capacitors 34 are connected

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The theoretical op ration of th circuit is seen with r f rence to Fig. 20, an equivalent circuit of the upper and underground power lin , which also shows the LRC values required to match the coupler to the power lin . At primary resonation, th LC impedances will be zero at transmission and reception such that the resistivity of the primary coil RT matches the input impedance of the power-line. On the receiver side, RR, has to be larger than the input impedance of the power line. These relationships facilitate long of the power line. These relationships facilitate long distance communication.

The coupling means 14, 22 shown in Figs. 6, 7, 8, 9A and 9B are suitable for communication in association with wide range of power-line voltages. As will be discussed herein, they can be utilized for high voltage, low voltage, LAN and phone line communications, as well as for communication directly through power line transformers.

A. Communication Options

1. Computer communication through Power and Phone Lines

utilizes the modems shown in Figures 10A, 11 and about 1.6 cm, #30 magnet gauge wire. The system and a secondary winding 48 with a coil diameter of mary winding 46 of 2.2 cm, #34 gauge magnet wire magnet wire. The second air coil 44 should have a pri-40 with a coil diameter of about 1.6 cm, #34 gauge of 2.2cm, #26 gauge magnet wire secondary winding should have a primary winding 38 with a coil diameter pacitance of 100 nanofarads. The first air coil 36 capacitor having a 1.6KV working voltage and a capluralities of capacitors 34, 42 as shown therein, each 1KVAC. The coupler preferably uses first and second 117.5 KHz for FSK) over power-lines 12 of up to about ond carrier frequency FB of around 111 KHz (and of around 75 KHz (and 81.5 KHz for FSK) and a secmeans 14 preferably use a first carrier frequency FA to 10 Kilobaud. For this application, the coupling munications and facilitate communication speeds up plied to LAM (local area network) and phone line com-The couplers of the present invention can be ap-

On the other side of the system, coupling means 22 comprises first and second pluralities of capacitors 34, 42 as shown therein, each capacitor having a 1.6KV working voltage and a capacitance of 100 nanotarade, along with the non-linear air coil transformer. As above, the first air coil 36 should have a primary winding 38 with a coil diameter of 2.2 cm, #36 gauge magnet wire. The a coil diameter of 1.6 cm, #34 gauge magnet wire. The second air coil 44 should similarly have a primary winding 46 of about 2.2 cm, #34 gauge magnet wire and a secondary winding 48 with a coil diameter of and a secondary winding 48 with a coil diameter of about 1.6 cm of #30 gauge magnet wire.

windings 46, 48. In the receiver transformer, the ratio of the primary and secondary windings must be greater than or equal to 1:1, at carrier frequencies below 1:1 at carrier frequencies below 1:1 at carrier frequencies of the may below 1:1 at carrier frequencies of the named this ratio can be altered or modified, such a change requires a resultant alteration in the size of the air gap, i.e. the relative ratio of 2R and 2r. The capacitor network C_(eq2) is set to resonate with the primary winding at carrier frequency on the size primary winding at carrier frequency cy FB.

In operation, the power line voltage is significantly reduced by C_{eq2} and the resistors. Thus, the created capacitance with the secondary winding significantly attenuates the harmonics and 60Hz signal to about zero, thus effectively functioning as a high pass filter. The carrier frequency voltage is thereby maximized. The sir coil produces a signal having a wider bandwidth than previous systems. The bandwidth characteristics of the present invention are shown in Figure 5. For reception, the resistivity of the primary should 5. For reception, the resistivity of the primary should be greater than the impedance of the power line.

From a design standpoint, then, the philosophy is to minimize the 60Hz line voltage and its harmonics. The circuit can be thought of as a series CRL circuit on the transmission side where: for the primary;

Sud for the secondary; $V_{PRIMARY(80Hz)} = V_{Power - line}(ZI)/(Zc)$

frequency characteristic ratio which will always be sround 100dB or greater. Preferably, a higher carrier frequency characteristic ratio which will always be around 100dB or greater. Preferably, a higher carrier frequency should be used for higher power line voltages. On the receiver side, the ratio of the impedances of inductance to capacitance, i.e. ZL/ZC must be minimized. Thus, ZC should be maximized at 60Hz. Consequently, because I_{60Hz} = VPL/ZC, ZC should be maximized at 60Hz.

in both directions. this coupling technique, because attenuation is equal pects of power-line transformers are irrelevant using of part of the power line. The step-up or step-down asmary air coil to the power line, which will be a function ing can be achieved using the resistivity of the priline transformers. Consequently, impedance matchthe air coil and no impedance effect from other power ates no impedance effect from the secondary side of are eliminated. The use of air coil transformers crenone of the 60Hz signal, the majority of the harmonics signal and because the nonlinear transformer passes is generated by the harmonics of the 60Hz power line is concentrated below 10KHz. Because system noise in the art that the noise component of the 60Hz signal transformers. It is to be appreciated by those skilled sible to communicate directly through power line its harmonics below 10KHz. The above makes it posgap) serve to completely filter the 60Hz current and earity of the transformers (i.e. the existence of the air The above relationships coupled with the non-lin-

12A.

Transformers

3. Communication Through Power Lin

2. High Voltage Pow r Lin Communications

As not d abov , the communication apparatus of th pres nt inv ntion may also be utilized for communication through power-line transformers (See Figure 122). The couplets permit communication through transformers at communication speeds of up to 1200 band. It is to be appreciated that for communication through the transformer in FSK, BPSK or Spread through the transformer in FSK, BPSK or Spread through the transformer in FSK, BPSK or Spread 12.9 KHz, using half-duplex with $F_1 = 12.1$ KHz $F_2 = 5$ Pectrum using half-duplex with 6 Megachm/5 Watts resistors (4.5KVAC) capacitors with 6 Megachm/5 Watts resistors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the tors (up to 22 KV power-line), the bandwidth of the

Fig. 9C illustrates a half-duplex coupler for data communication through the high voltage side of distribution transformers. In this system three solenoids (aircoils) having three different diameters are utilized. The diameter of outer coil 54 is 11.4 cm, #26 gauge magnet wires, the middle 56 is 8.9 cm, #26 gauge magnet wires, the middlest 58 is 8.0 cm, #30 gauge magnet wire. The largest diameter outer coil 54 is the primary which resonates with the capacitor, the middle is the transmitter coil 56 and the narrowest is middle is the transmitter coil 56 and the narrowest is the receiver coil 58. For reception, the transmitter coil from the transmitter coil for norder to have transmitter coil receiver coil is uncoupled. In this contiguration, noise teceiver coil is uncoupled. In this contiguration, noise teceiver coil is uncoupled. In this contiguration, noise teceiver coil is reduced significantly, and the carrier teceiver coil is reduced significantly, and the carrier teceiver coil is reduced significantly, and the carrier

On the low power side of the power line distribution transformer corresponding to the 120, 240 and 480 V power lines, the system can be configured to use the same carrier frequency, with one coupler on the low voltage side (i.e. a single primary and single secondary). (See Figure 22). The transformer is coupled to two 250 nanofarad capacitors (500 VAC). In this situation, the primary coil 38 has a diameter of this situation, the primary coil 38 has a diameter of 4.0 cm using #26 gauge magnet wire with the secondary coil 40 having a diameter of 3.8 cm using #34 ary coil 40 having a diameter of 3.8 cm using #34

It is to be appreciated that the couplers of the present invention will permit more than one carrier signed to be simultaneously transmitted.

8. Transmitter and Receiver Devices

gauge magnet wire.

The preferred transmitter 16, 24 useful in the power-line communication of data signals over long distances is shown in Fig. 11. This transmitter can be utilized in all of the applications of the present invention, including transmission through power line transform, including transmission through power line transform, including transmitter means generally comprises a driver 62 which is connected to the coupling means of the transmitter of the coupling means 14, 22 by way of their respective connections TFA/B1, 14, 22 by way of their respective connections TFA/B1, transistors 66, 68, the transmitter 16 while comparationally slow, is more powerful for long distance (i.e., 10 tively slow, is more powerful for long distance (i.e., 10

large high voltage transmission lines. typically be located at a ground station adjacent to lliw bas teet neettit yletsmixorqqs to tagied a gaivan that the above system will be comparatively large, MegaOhm per 5 watt resistors. It is to be appreciated nanofarad capacitors connected in series, with 5 suitably comprises one branch of three hundred 100 and connected in series, while the second plurality 42 branches of three hundred 100 nanofarad capacitors 8. The first plurality 34 suitably comprises two parallel somewhat modified over what is shown in Figs. 7 and first 34 and second 42 pluralities of capacitors are respectively, are preferred, and the connections of and FB camer frequencies of 80 KHz and 120 KHz, up to 9600 band. In this application first FA and secinvention can be utilized for communication speeds voltages of up to 750KV. The couplers of the present KVDC/4.5KVAC capacitor can b used for power-line power line communication applications in which a 15 The couplers are alse applicable to high voltage

Referring to the non-linear transformers for this application, the first sir coil 36 of the coupling means 14 suitably comprises a primary winding 38 with a coil dismeter of 10 cm, #20 gauge magnet wire. The second sir coil 44 cm of #26 gauge magnet wire. The second sir coil 44 likewise suitably comprises a primary winding 46 of 10 cm, #20 gauge magnet wire, and a secondary winding 48 with a coil dismeter of 6.0 cm, #26 gauge magnet wire. The inductivity of the primary is calcumagnet wire.

eter of about 6.0 cm, #28 gauge magnet wire. net wire and a secondary winding 48 with a coil diames a primary winding 46 of 10.0 cm, #20 gauge magwire. The second air coil 44 likewise suitably compriswith a coil diameter of 6.0 cm, #26 gauge magnet #20 gauge magnet wire and a secondary winding 40 es a primary winding 38 with a coil diameter of 10 cm, itors connected in series. The first air coil 36 compristwo branches of three hundred 100 nanofarad capacies, while the second plurality 42 suitably comprises hundred 100 nanofarad capacitora connected in serplurality 34 suitably comprises one branch of three plurality 34, 42 being connected in parallel. The first ially connected capacitors, all of the branches of each 34, 42 comprising a number of branches of 300 sercircumstances also includes the capacitor pluralities The identical coupling means 22 under the same

Figure 21 is a graph of power-line attenuation versus carrier frequencies on the 35 KVAC power line for 20 KM distances. A 150 ohm load was used for the matching conditions. The best range of communication can be seen here from 70 to 160 KHZ. As the number of transformers in the power line increase, the attenuation of the power line will increase especially above 100 KHz.

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n rfrequ ncies (FA and FB). The values of C_1 , R_3 and R_4 are varied to alter th FA and FB carri r frequ n-

Figure 10B illustrates an alternative FM modulator sor and d modulator 20' for high frequency communication. The cation for LAN and phone line communication. The circuit incorporates the XR-210 FSK demodulator 103, XR-2207 FSK 105 generator and MAX232 107 computer input/output interface. The values for R₀, C₀, C₁, C₂, C₃, and C₄ are utilized to alter the carrier frequencies (FA and FB). The values of C₁, R₃ and R₄ are varied to alter the FA and FB carrier frequencies (FA and 10D illustrate addition modulator derivative 10C and 10D illustrate addition modulator derivative 10C and 10D illustrate addition modulator circuits 20", 20" which can be utilator/demodulator circuits 20", 20" which can be utilatory and can be utilated as a contraction of the computer circuits 20", 20" which can be utilated as a contraction of the computer circuits 20", 20" which can be utilated as a contraction of the computer circuits 20", 20" which can be utilated as a contraction of the computer circuits 20", 20" which computer circuits 20", 20", 20" which computer circuits 20", 20" which circuits 20", 20" which circuits 20",

tor/demodulator circuits 20", 20" which can be utilized in the present invention. Figure 10C shows an FSK decoder using the 565 interface 109. The loop filter capacitor is chosen to set the proper overshoot on the output and a three-stage RC ladder filter is used to remove the noise frequency component. As shown in Figure 10D, another FSK chip, the XR2211 111, can be used to demodulate and the XR2207 (not shown) can be used for modulation.

Modem Circuits

Figures 18 and 19 illustrate two complete modem configurations which can be utilized in the present invention. Figure 18 is a spread spectrum transmission and receiver modem. This circuit is suited for communication through high voltage AC and DC power lines nication through high voltage AC and DC power lines and for communication through transformers. The spread spectrum modem can be demodulated in high noise levels.

Figure 19 illustrates a Bi-Polar Shift Keying transmission and receiver modern circuit particularly applicable for phone line and LAM communication. This circuit includes an XR 2123 modulator/demodulator 113, XR2208 Operation Multiplier 115, and DM74193 synchronous up/down counter 117. This circuit requires a smaller bandwidth for communication than FSK because it uses only one carrier frequency while changing sine and cosine waves. The carrier frequency while changing sine and cosine waves. The carrier frequency must always be at least 10dB above the noise.

Operational Example

The particular attributes of the apparatus and configurations of the present invention are perhaps best illustrated in view of the following comprehensive example described with reference to Figures 22-sive example utilizes most of the coupler configurations and modems discussed above and illustrates how the communications apparatus and novel couplers of the present invention can be utilized in a comprehensive system using LAM, phone line, high voltage and low voltage power line communications, as well as communication through power line trans-

miles) power syst m communication, especially ov rhigh voltag p wer lines. Suitable transistors 66 for this transmitter are conventional SK3444, while the transmistors 68 may suitably comprise conventional SK3444, while the transmistors 68 may suitably comprise conventional SK3024. For higher pow r transmission, SM3055 transistors may be utilized instead of SK3024. The particular value of each resistor and capacitic operating in Fig. 11 will depend upon the specific operating characteristics of the driver but they would be readily exemplary skill in the art of electronics. Nevertheless, of ordinary skill in the art of electronics. Nevertheless, of ordinary skill in the art of electronics and capacitors are exemplary values of the resistors and capacitors are shown in Fig. 11.

pled to magnetic coil 64 (band pass filter) which filters signal wave. Another feature is the notch filter 79 coupotentiometer 75 which biases out noise around the feature of the receiver of Figure 12 is the inclusion of resistors and capacitors are shown in Fig. 12. A key electronics. Nevertheless, exemplary values of the experimentation by one of ordinary skill in the art of but they would be readily ascertainable without undue specific operating characteristics of the receiver 18, and capacitor shown in Fig. 12 would depend upon tional SK3444. The particular value for each resistor power lines. Suitable transistors 66 are also conventem communication, especially over high voltage powerful for long distance (i.e., 10 miles) power sysily apparent that the receiver means 18, 26 is more tions RFAB, RFABGND and RFABC. It will be readpling means 14, 22 by way of their respective connecceiver means 18, 26 is similarly connected to the counals over long distances is shown in Fig. 12. The reuseful in the power-line communications of data sig-The preferred receiver means 18, 26 which is

Figure 12A shows an additional receiver 18', 26' which can be utilized between 120V and 240V including FSK, and which is particularly suited for low voltage LAN and telephone line communications. In this receiver, C_1 and R_1 are used for F1; and C_3 and R_2 are used for F2 in a high pass configuration. In a low pass configuration, C_2 and L_1 are used for F1 and C_4 and L2 are used for F2. The receiver further utilizes a notch filter 83 coupled to band pass filter 85 which filters out transmission frequencies.

out transmission frequencies on the same side.

C. Modulator/Demodulator Circuits

The modulation and demoludation of the data signals is now described with reference to Figures 10A and 10B. Figure 10A illustrates an FM modulator and demodulator 20. This circuit is perticularly applicable for high voltage communication through power-line transforvoltage communication through power-line transformers. The circuit comprises an XR-2211 FSK demodulator 97 XR-2207 FSK generator 99 and MAX232 ulator 97 XR-2207 FSK generator 99 and MAX232 computer input/output interface 101. The values for computer input/output interface 101. The values for

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at a work station may acc as th VAX computer through the power lines of the facility via moderns and high speed LAN or phon line couplers of the present invention at data transmission spe ds of up to 10 Kbaud.

water meter reading. izes the couplers at a second carrier frequency for reading at a first frequency while a water utility utilously utilized by an electric utility for electric meter the couplers. Hence, the couplers can be simuntaneception of more than one carrier frequency through tion will permit the simultaneous transmission and re-It is to be noted that the couplers of the present inventhrough power line transformers as discussed above. voltage couplers designed for communication In this configuration, the couplers will comprise low 145 and through a three phase large transformer 147. to communicate through two power line transformers the couplers of the present invention can be utilized tem of Figure 22. Figure 25 is a block diagram of how simplified block diagram of the communication sysand through distribution transformers. Figure 24 is a ters at 1200 baud via high voltage distribution lines substations then communicate with the individual meetc.) over conventional phone lines. The respective puter communicates with each substation (1, 2, 3, to a multiplicity of couplers 143. As shown, the commeters via a master modern and multiplexer coupled computer would simultaneous read a large number of tiplicity of substations. In this embodiment the central tem which may be utilized by a utility to meter a mul-Figure 23 is a block diagram of an expanded sys-

A final consideration of the present invention is the connection of the apparatus to a three phase power et line. Figure 13 illustrates the general case of coupling the apparatus to the power line, phase to ground. In this format, the carrier frequency is undescrible by other phase-ground coupling connections and each phase is isolated from each other for communication purposes. Figure 14 illustrates a special three phase coupling connection to the power line, 3 phases to ground. This system utilizes all three phase to ground. This system utilizes all three phase of the carrier frequency is detectable on any other phase-ground coupling connection. In this manner, the phases are interconnected for communication.

Figure 15 illustrates a special two phase coupling connection to the powerline, phase to phase 147. This system utilizes two phases from the power line for communication. The carrier frequency is detectable only on the two phase coupling connection. In this configuration, only the coupled two phases are connected for communication purposes.

Figure 16 illustrates a three phase transformer coupling stround delta and Y (Mye) transformers 149. This coupling system is generally utilized in Europe. The camer frequency is directable on the other pow-

formers.

KV power lines 129 on the utility pole. transformer will be connect to one of the three 13.2 disclosed in Figures 10A, 11 and 12. The distribution ceivers, modulators/demodulator, or modem circuits above. The system will utilize the transmitters, retransformers such as discussed in section A.3. uration capable of communicating through power line house. The couplers will have the low voltage configsituated on the utility pole 127 located adjacent to the nect to the 240 low volt distribution transformer 126 electricity meter 125. The couplers 123 would conaccordance with the present invention coupled to the air coil transmitter and receiver coupler circuit 123 in power from the utility would have a modem 121 and In this xample, each home 119 receiving electric electric power utility for reading home power met rs. of the pr sent inv ntion as they may utilized by an Figure 22 illustrates an example of the couplers

At the other end of the system situated at a local substation 131, a second substation modem 133 is connected to one of three couplers 135 in accordance with the present invention. The couplers are encased in resin, as disclosed above, and will preferably have the high voltage side transformer configuration set forth in Figure 9C. The substation is itself connected via couplers 137 such as disclosed in section A.1 to the large central computer 139 of the utility (generally puter 139 will communicate via high speed communicate of the substation 131 and computer 139 will communicate via high speed communicate up to 10K baud as set forth herein using the transmitter, receiver and modulatory demodulator circuits of Figs. 10B, 11 and 12A.

for power transmission in both directions. The system only requires between one and ten watta tion coupler 135 and to the substation modem 135. the 13.2 KV power line 129 to the appropriate substaplers 123, through distribution transformer 126, over ed, transmitted by the home modem 121 through couplers 123 and modem 121. A meter reading is recordthe distribution transformer, through the home couthe 13.2 KV line at speeds up to 1200 baud, through dem and couplers. The command is transmitted over addressable command the particular meter via mophone lines 138. The substation will then transmit an speeds up to 10K baud over power or conventional 141 and coupler 137 to the particular substation at command which is transmitted via a master modem the central computer 139 will issue an addressable When the utility desires to make a meter reading,

From the substation, the meter reading may be transmitted via conventional phone lines 138 to the central computer 139. Additionally, as shown in Figure 22A the high speed phone line and LAN couplers of the present invention could be used within the utility to connect local workstations 141 to the central comput r 139. For exampl, a clerical work r situat d

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reasoding bui

4. The communication apparatus of daim 1, further charact rized by

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said electrical line (12),
- demodulator means (28) for demodulating
said pres lected carrier frequency signal,

- second coupler m ans (22) conn cted to

- receiver means (26) coupled to said second coupler means (22) for conducting said modulated carrier signal to said demodula-
- tor means (28),

 said second coupler means (22) including in

 combination a second sir-core transformer

 means (44) and a second capacitor means

 (42) forming a second LC circuit (32) that

 provides an input impedance which corresponds to the characteristic output impeands

 sponds to the characteristic output impeands
- 5. The communication apparatus according to claim 2, characterized
 by the ratio of the number of turns of said

selected high band carrier frequency.

dance of the electrical line (12) at said pre-

- primary winding (38) to said secondary winding (40) is about one to one.
- 6. The communication apparatus according to claim 2, characterized by
- the combination of the capacitance created between said primary winding (38) and said secondary winding (40) of said sir-core transformer means (36) functioning as a high-pass filter.
- The communication apparatus of claim 4 characterized by
- said second air-core transformer means (44) having a primary winding (46) having a first diameter, said primary winding (46) being coupled to said capacitor means (42) and
- a secondary winding (48) having a second smaller diameter, said secondary winding (48) extending coaxially within said primary winding (46) such that an air gap is created between said primary winding (46) and said secondary winding (48).
- 8. The communication apparatus according to claim 1, characterized by
- cisim 1, cristactenzed by
 said high band frequency being less than about 1 MHz.
- The communication apparatus according to claim 1, characterized by
 claim 1, characterized by
- about 160 KHz.
- 10. Th communication apparatus according to

er lin s are connected to ach other for communication purposes. Finally, Figure 17 illustrates a one phase transformer coupling which is gen rally used in the U.S.A. In this manner, the carrier frequency is detectable on the other power lines are connected to each ferent high voltage power lines are connected to each other for communication purposes.

It is to be understood, therefore, that within the scope of the appended claims, the present invention may be practiced otherwise than as specifically described herein.

Claims

- 1. Communication apparatus comprising coupler means (14,22), connected to an
- electrical line (12), having a characteristic output impedance,
 said coupler means (14,22) including trans-
- former means (36) characterized by modulator means (20,28) for modulating a
- preselected carrier frequency signal having a high band frequency,
 transmitter means (16,24) coupled to said modulator means (20,28) for transmitting
- transmitter means (16,24) coupled to said modulator means (20,28) for transmitting said modulated carrier signal to said coupler means (14,22),
- said transformer means (36) being air-core transformer means,
- eaid sir-core transformer means (36) being stranged in combination with capacitor means (34) forming an LC-circuit (30) that provides an input impedance which corresponds to the characteristic output impedance of the electrical line (12) at said predance of the electrical line (12) at said predence of the band carrier frequency.
- 2. The communication apparatus of claim 1, characterized by
- said air-core transformer means (36) including a primary winding (38) having a first diameter and coupled to said capacitor means (34), and
- a secondary winding (40) having a second smaller diameter and extending coaxially within said primary winding (38) such that an air gap is created between said primary winding and said secondary winding.
- The communication apparatus of claim 1 characterized by
- said air-core transformer means (36) functioning as a phase linear inductively and calunctively coupled transformer.

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first r c iv rmesns (26) for modulating signals nals to be carri d by said first carri r frequency and f r demodulating said signals carried by said s cond carrier frequency, said s cond coupl r means (22) including two LC circuits (34,42), coupled to said

- electrical line (12),

 both said LC circuits (34,42) including capacitor means (34) and resistor means (35),

 consisting of at least one capacitor and at least one resistor, connected in parallel to each other and in series between the electrical line (12) and the primary induction thical line (12) and the primary induction winding (46) of said air-core transformer
- means (44),
 second transmitter means (24), coupled to
 said second coupling means (22) of the secondary induction winding (48) of said sir-core transformer means (44) for transmitting
 re transformer means (44) for transmitting
- cy across the electrical line-(12),
 second receiver means (18), connected to
 said second coupling means (22) at the secondary winding (40) of said air-core transformer means (36) that is not connected to
 said transmitter means (24) for receiving
 said transmitter means (24) for receiving
 signals carried by a first carrier frequency
 from the electrical line (12),
- a second modern means (23), coupled between said second transmitter means (24) and said second receiver means (18) for demodulating said signals to be carried by said first carrier frequency and modulating said signals carrier frequency and modulating frequency.
- 15. The communication apparatus according to claim 14, characterized by
- said LC circuits of said first and second coupler means (14,22) comprising a first plurality of capacitors and a first air coil including primary and secondary winding being
 the diameter of said primary winding being
 the diameter of said primary winding being
 the diameter of said secondary
 greater than the diameter of said secondary
 winding thereby creating an air core be-
- ings,

 the other LC circuit being connected in parallel to the electrical line (12) and comprises
 a second plurality of capacitors and a second sir coil including primary and secondary windings, the diameter of said primary
 winding being greater than the diameter od
 winding being greater than the diameter od
 said secondary winding thereby creating an
 sir-core between said primary and secondsir-core between said primary and secondstry windings,

tween said primary and secondary wind-

- wherein said first plurality of capacitors are connected tog th r in parallel betw n one

daim 4, characterized by

- said high band frequ ncy, measured at a point betw n said receiver means (26) and said second coupler means (22) comprising noise reduction of about twenty d cib is at the band-

11. The communication apparatus according to claim 2 characterized by

width.

- said sir-coils (36,44) comprising impedance matching means such that the primary winding (38) resistivity for transmission and reception at a preselected carrier frequency is about equal to the smallest known characteristic impedance of the electrical line (12).
- 12. The communication apparatus according to daim 1, characterized by
 said coupler means (14,22) resonating at asid preselected carrier frequency.
- 13. The communication apparatus of daim 1 characterized by
 said transmitter means (16,24) simulta-
- neously transmitting at least a second carrier signal having a second frequency through said coupler means (14,22).
- 14. The communication apparatus according to daims 1 to 4, characterized by
- said first coupler means (14) including two
 LC circuits (34,42), coupled to said electrical line (12),
 both said LC circuits (34,42) including an
- RC circuit comprised of a capacitor means (34) and a resistor means (35), each consisting of at least one capacitor and at least one resistor, connected in parallel to each other,
- said primary winding (38) of said air-core transformer means (36) being connected in series with said RC circuit and said electrical line (12),
- said first transmitter means (16) being coupled to said first coupler means (14) at the secondary winding (40) of said air-core transformer means (36) for transmitting signals carried by a first carrier frequency across said electrical line (12),
- said first receiver means (26) being coupled
 to said first coupling means (14) at the secondary winding (48) of the air-core transformer means (44), that is not connected to
 said transmitter means (16) for receiving
 signals carried by a second carrier frequensignals carried by a second carrier frequen-
- a first modem means (21) coupled between said first transmitter means (16) and said

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- 22. The communication apparatus according to claim 14 characterized by
- th capacitanc created b tw n the respective primary windings (38,46) and secondary windings (40,48) of said sir-core transformers (36 and 44) functioning as a high-pass filter with the secondary windings (40,48).
- 23. The communication apparatus according to claim 14 characterized by
- the primary windings (38,46) of said first and second coupler means (14,22) with said capacitors functioning as a band-pass filter.
- 24. The communication apparatus according to claim 14 characterized by
 said resistors of the first coupler means
 (14) dividing down the AC/DC voltages over said

capacitor and resistor circuit.

- 25. The communication apparatus according to claim 14 characterized by

 said resistor(s) of the second coupler
- said resistor(s) of the second coupler means (22) dividing down the AC/DC voltages over said capacitor and resistor circuit.
- 26. The communication apparatus according to claim 24 characterized by

 said capacitors of the first coupler means

 (14) resonating with the primary winding (38) of
- (14) resonating with the primary winding (38) of said first air-core transformer means (36).
- 27. The communication apparatus according to claim 24 characterized by- said capacitors of the second coupler
- means (22) resonating with the primary winding (46) of said second air-core transformer (44).
- 28. The communication apparatus of daim 1 characterized by
- said capacitor (34) consisting of at least one capacitor and said coupler means (14) further comprising a resistor means (35) which in combination with said LC circuit (30) forms first LC means, said resistor means (35) consisting of at least one resistor, said capacitor means (34) and said resistor means (35) connected in parallel to each other and in series to said electrical line (12).
- 29. The communication apparatus of claim 28 characterized by
 said coupler means (14,22) further com-
- prising a second LC means.
- 30. Th communication apparatus of daim 4 charac-

- of th pow r-lines of the electrical line (12) and said primary winding of said first sir coil,
- said primary winding of said first air coil

 th r aft r b ing serially connected t th

 other power-line of said electrical line (12),

 and said secondary winding of said first air

 coil is connected to its respective transmit
 ter means, and

 ter means, and

 wherein said second plurality of capacitors
- wherein said second plurality of capacitors
 are senally connected together between
 said one of the power-lines of said electrical
 line (12) and said primary winding of said
 second air coil, said primary winding of said
 second air coil thereafter serially connected
 to the other power-line.
- 16. The communication apparatus according to daim 14, characterized by
 said first and second coupler means (14,22) each having a bandwidth of less than about 200 KHz.
- 17. The communication apparatus according to daim 14, characterized by

 said first and second coupler means (14,22) each having a bandwidth of less than about 20 KHz.
- 18. The communication apparatus according to daim 14, characterized by

 the induction component of said LC circuits in each of said first and second coupler
- cuits in each of said first and second coupler means (14 and 22) being characterized as comprising two air-core inductors (36 and 44) combined to act as a capacitive air-core transformer which is inductively and capacitively coupled and phase shift linear.
- 19. The communication apparatus according to daim 14 characterized by
- the primary and secondary windings of said first and second air-core transformer means (36,44) functioning as an inductively and capacitively coupled transformer.
- 20. The communication apparatus according to daim 14 characterized by

 the ratio of the number of turns of said
- the ratio of the number of turns of said primary winding (38) to said secondary winding (40) in said first air-core transformer means (36) being about one to one.
- 21. The communication apparatus according to daim 14 characterized by

 the ratio of the number of turns of said
- the ratio of the number of turns of said primary winding (46) to secondary winding (48) in said second air-core transformer means (44) be-

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eine Modulatoreinrichtung (20, 28) zur Modulation eines vorgewählten Trägerfrequenzsignals mit einer hohen Frequenz,
 eine mit der Modulatoreinrichtung (20, 28)

- eine mit der Modulatoreinrichtung (20, 28)
 gekopp Ite Sendeeinrichtung (16, 24) zum übertragen des modulierten Trägersignals auf die Kopplereinrichtung (14, 22),
- aur die Aoppiereinnchtung (14, 22),

 die Übertragereinnichtung (36) ist eine eine seinlose Übertragereinnichtung,
- die eisenlose Übertragereinrichtung (36) ist in Kombination mit einer Kondensatoreintrichtung (34) zur Bildung eines LC-Kreises richtung (34) zur Bildung eines LC-Kreises (30) angeordnet, der eine Eingangsimpedanz der charakteristischen danz bereitstellt, die der charakteristischen Ausgangsimpedanz der Elektrizitätsleitung (12) bei der vorgewählten hohen Trägerfrequenz entspricht.
- Kommunikationseinrichtung nach Anspruch 1, gekennzeichnet durch
- die eisenlose Überträgereinrichtung (36)
 umfaßt eine Primärwicklung (38), die einen ersten Durchmesser aufweist und die mit der Kondensatoreinrichtung (34) gekoppelt ist, und
- eine Sekundärwicklung (40), die einen zweiten kleineren Durchmesser aufweist und die sich koaxial innerhalb der Primärwicklung (38) so erstreckt, daß ein Luftspalt zwischen der Primärwicklung und der Sekundärwicklung gebildet ist.
- 3. Kommunikationseinrichtung nach Anspruch 1, gekennzeichnet durch
- die eisenlose Übertragereinrichtung (36) wirkt als phasenlinearer induktiv und kapazitiv gekoppelter Übertrager.
- Kommunikationseinrichtung nach Anspruch 1, ferner gekennzeichnet durch
- eine zweite mit der Elektrizitätsleitung (12)
- verbundene Kopplereinrichtung (22),
 eine Demodulatoreinrichtung (28) zur Demodulation des vorgewählten Trägerfrequenzsignals, und
- eine mit der zweiten Kopplereinrichtung (26)
 (22) gekoppelte Empfangseinrichtung (26)
 zum Übertragen des modulierten Trägersignals zu der Demodulatoreinrichtung (28),
 die zweite Kopplereinrichtung (22) umfaßt
- in Kombination eine zweite eisenlose übertragereinrichtung (44) und eine zweite Kondensatoreinrichtung (42) zur Bildung eines zweiten LC-Kreises (32), der eine Eingangsimpedanz bereitstellt, die der charakteristischen Ausgangsimpedanz der Elektrizitätsleitung (12) bei der vorgewählten thohen Trägerfrequenz entspricht

- said capacitor m ana (34) of said second coupl r means (22) consisting 1 at least one capacitor and said second coupler m ans (22) further comprising a resistor m ans (35) which in combination with second LC circuit (32) forms a third LC means, said resistor means (35) consisting of at least one resistor, said capacitor means (34) and said resistor means (35) connected in

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parallel to each other and in series to said electrical line (12).

31. The communication apparatus of claim 30 char-

- acterized by
 said second coupler means (22) further comprising a fourth LC means.
- 32. The communication apparatus of claim 29 characterized by acterized by LC means and said second LC
- said first LC means and said second LC means connected in parallel to said electrical line (12).
- 33. The communication apparatus of claim 32 characterized by
- said third LC means and said fourth LC means connected in parallel to said electrical line (12).
- 34. The communication apparatus of claim 32 characterized by
 said third LC means and said fourth LC means connected in parallel to said electrical line
- 35. The communication apparatus of claim 14 characterized by
 said two LC circuits (34,42) of said first
 coupler means (14) connected in parallel to said
- 36. The communication apparatus of claim 14 characterized by
- said two LC circuits (34,42) of said second coupler means (22) connected in parallel to said electrical line (12).

Patentansprüche

electrical line (12).

(12).

terized by

- f. Kommunikationseinrichtung enthaltend:

 eine mit einer Elektrizitätsleitung (12) ver bundene Kopplereinrichtung (14, 22) mit ei
- danz,
 wobei die Kopplereinrichtung (14, 22) eine Übertragereinrichtung (36) umfaßt.

charakteristischen Ausgangsimpe-

gekennzeichnet durch

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gekennzeichnet durch - die Kopplereinrichtung (14, 22) schwingt mit b i der vorgewählten Trägerfrequenz.

- 13. Kommunikationseinrichtung nach Anspruch 1, gek_nnzeichnet durch
 die Sendeeinrichtung (16, 24) überträgt
- gleichzeitig wenigstens ein zweites Trägersignal mit einer zweiten Frequenz durch die Kopplerein-richtung (14, 22).
- chen 1 bis 4, gekennzeichnet durch
- die erste Kopplereinrichtung (14) umfaßt zwei LC-Kreise (34, 42), die mit der Elektri-
- zitätsleitung (12) gekoppelt sind,

 beide LC-Kreise (34, 42) umfassen einen RC-Kreis mit einer Kondensatoreinrichtung (34) und einer Widerstandseinrichtung (35), wobei jeder aus wenigstens einem Kondensator und wenigstens einem paral-
- lelgeschalteten Widerstand besteht, die Primärwicklung (38) der eisenlosen übertragereinrichtung (36) ist in Reihe geschaltet mit dem RC-Kreis und der Elektrizitätsleitung (12),
- die erste Sendeeinrichtung (16) ist mit der ersten Kopplereinrichtung (14) gekoppelt an der Sekundärwicklung (40) der eisenlosen übertragereinrichtung (36) zur Übertragung von Signalen, die von einer ersten gung von Signalen, die Kunzitätsleit Trägerfrequenz über die Elektrizitätsleit Tragerfrequenz über die Elektrizitätsleit
- tung (12) übertragen werden,

 die erste Empfangseinrichtung (26) ist mit

 der ersten Kopplereinrichtung (14) gekoppelt an der Sekundärwicklung (48) der eisenlosen übertragereinrichtung (44), die
 nicht mit der Sendeeinrichtung (16) verbunnicht mit der Sendeeinrichtung (16) verbunden ist, zum Empfangen von Signalen, die
 von einer zweiten Trägerfrequenz über die
 von einer zweiten (12) übertragen wer-
- den,

 eine erste Modulationseinrichtung (21), die

 zwischen die erste Sendeeinrichtung (16)
 und die erste Empfangseinrichtung (26) zur
 Modulation von Signalen eingekoppelt ist,
 die von der ersten Trägerfrequenz zu übertragen sind, und zur Demodulation von den
 Signalen, die von der zweiten Trägerfre-
- quenz übertragen werden,

 die zweite Kopplereinrichtung (22) umfaßt
 zwei LC-Kreise (34, 42), die mit der Elektri-
- zitätsleitung (12) gekoppelt sind,
 beide LC-Kreise (34, 42) umfassen eine
 Kondensatoreinrichtung (34) und eine Widerstandseinrichtung (35), die aus wenigstens stens einem Kondensator und wenigstens einem parall Igeschalt ten Widerstand beeinem parall Igeschalt ten Widerstand beeinem parall Igeschalt ten Widerstand be-

- 5. Kommunikationseinrichtung nach Anspruch 2, g kennzeichnet durch das V rhältnis der Windungszah-
- len der Primärwicklung (38) zu der Sekundärwicklung (40) ist etwa eins zu eins.
- Kommunikationseinrichtung nach Anspruch 2, gekennzeichnet durch
- die Kombination der Kapazität, die zwischen der Primärwicklung (38) und der Sekundärwicklung (40) der eisenlosen Übertragereinrichtung (36) gebildet wird, wirkt als Hochpasstilter.
- 7. Kommunikationseinrichtung nach Anspruch 4, gekennzeichnet durch
- die zweite eisenlose Übertragereinrichtung
 (44) weist eine Primärwicklung (46) mit einem ersten Durchmesser auf, wobei die Primärwicklung (48) mit der Kondensatoreinrichtung (42) verbunden ist, und
- eine Sekundärwicklung (48) mit einem zweiten kleineren Durchmesser, wobei sich die Sekundärwicklung (48) koaxiat innerhalb der Primärwicklung (46) so erstreckt, daß ein Luttspalt zwischen der Primärwick-lung (46) und der Sekundärwicklung (48)
- 8. Kommunikationseinrichtung nach Anspruch 1, gekennzeichnet durch- die Hochfrequenz ist niedriger als etwa 1

.ZHM

- 9. Kommunikationseinrichtung nach Anspruch 1, gekennzeichnet durch
 die Hochfrequenz ist niedriger als etwa
- 160 KHZ.

gebildet ist.

- 10. Kommunikationseinrichtung nach Anspruch 4, 40gekennzeichnet durch
- die Hochfrequenz gemessen an einem Punkt zwischen der Empfangseinrichtung (26) und der zweiten Kopplereinrichtung (22) weist eine Störunterdrückung innerhalb der Bandbreite von etwa zwanzig Dezibel auf.
- 11. Kommunikationseinrichtung nach Anspruch 2, gekennzeichnet durch
- die Luftspulen (36, 44) umfassen Impedanzanpassungseinrichtungen, so daß der spezifische Widerstand der Primärwicklung (38) zum Senden und Empfangen bei einer vorgewählten Trägerfrequenz etwa gleich ist der kleinsten bekannten charakteristischen Impedanz der Elektrizitätsleitung (12).
- 12. Kommunikationseinrichtung nach Anspruch 1,

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pun uap ntsprechend n S nd inrichtung verbunwicklung d rersten Luftspule ist mit s iner

mit der anderen Stromversorgungsleitung. spule anschließend in Reihe geschaltet ist bei die Primärwicklung der zweiten Luft-Primärwicklung der zweiten Luftspule, wotung der Elektrizitätsleitung (12) und der zwischen der einen Stromversorgungsleitoren mit inander in Reih g schalt t ist - wobei die zweite Mehrzahl von Kondensa-

- die erste und zweite Kopplereinrichtung gekennzeichnet durch 16. Kommunikationseinrichtung nach Anspruch 14,

niger als etwa 200 kHz auf. -ew nov efierdbraß erie eliewei nesiew (SZ, Ar)

gekennzeichnet durch 17. Kommunikationseinrichtung nach Anspruch 14,

(14, 22) weisen jeweils eine Bandbreite von we-- die erate und zweite Kopplereinrichtung

niger als etwa 20 kHz auf.

gekennzeichnet durch 18. Kommunikationseinrichtung nach Anspruch 14,

near ist kapazitiv gekoppelt und phasenverschiebungslieisenloser Ubertrager zu wirken, der induktiv und und 44), die kombiniert sind, um als kapazitiver halten von zwei eisenlosen Induktionsspulen (36 fung (14 und 22) ist gekennzeichnet durch Entin jeder der ersten und zweiten Kopplereinrich-- die induktive Komponente der LC-Kreise

gekennzeichnet durch 19. Kommunikationseinrichtung nach Anspruch 14,

zitiv gekoppelter Übertrager. richtungen (36, 44) wirken als induktiv und kapaersten und zweiten eisenlosen Ubertragerein-- die Primär- und Sekundärwicklungen der

20. Kommunikationseinrichtung nach Anspruch 14,

der Primärwicklung (38) zu der Sekundärwic-- das Verhältnis der Zahl der Windungen gekennzeichnet durch

einrichtung (36) beträgt etwa eins zu eins. klung (40) in der ersten eisenlosen Ubertrager-

gekennzeichnet durch 21. Kommunikationseinrichtung nach Anspruch 14,

einrichtung (44) beträgt etwa eins zu eins. klung (48) in der zweiten eisenlosen Ubertragerder Primärwicklung (46) zu der Sekundärwic-- das Verhältnis der Zahl der Windungen

g kennz ichnet durch 22. Kommunikationseinrichtung nach Anspruch 14,

> einrichtung (44) geschaltet sind, wicklung (46) der eisenlosen Ubertragertätsleitung (12) und di Primärinduktionsstehen und in Reih zwischen di Elektrizi-

-sngi2 nənəgsitrədü znəupərtragsiT ətzrə bunden ist, zum Empfangen von über eine die nicht mit der Sendeeinrichtung (24) ver-Ubertragereinrichtung (36) verbunden ist, der Sekundärwicklung (40) der eisenlosen mit der zweiten Kopplereinrichtung (22) an eine zweite Empfangseinrichtung (18), die tung (12) ūbertragen werden, gekoppelt ist, Trägerfrequenz über die Elektrizitätsleitragen von Signalen, die von einer zweiten sen Ubertragereinrichtung (44) zum Uberkundärinduktionswicklung (48) der eisenloder zweiten Kopplereinrichtung (22) der Se-- ine zweit S nde inrichtung (24), die mit

tragen werden, eingekoppelt ist. die von der zweiten Trägerfrequenz übersind, und zur Modulation von den Signalen, der ersten Trägerfrequenz zu übertragen (18) zur Demodulation der Signale, die von (24) und die zweite Empfangseinrichtung die zwischen die zweite Sendeeinrichtung - eine zweite Modulationseinrichtung (23), len von der Elektrizitätsleitung (12),

gekennzeichnet durch 15. Kommunikationseinrichtung nach Anspruch 14,

ste Luftspule mit Primär- und Sekundärwic-Mehrzahl von Kondensatoren und eine erlereinrichtung (14, 22) umfassen eine erste die LC-Kreise der ersten und zweiten Kopp-

kern zwischen den Primär- und Sekundärwicklung und erzeugt dadurch einen Luftgrößer als der Durchmesser der Sekundär-- der Durchmesser der Primärwicklung ist klungen,

 wobei die erste Mehrzahl von Kondensato-Primär- und Sekundärwicklungen erzeugt, und dadurch einen Luftkern zwischen den der Durchmesser der Sekundärwicklung messer der Primärwicklung größer ist als Sekundärwicklungen, wobei der Durchund eine zweite Luftspule mit Primär- und eine zweite Mehrzahl von Kondensatoren trizitätsleitung (12) geschaltet und umfaßt der andere LC-Kreis ist parallel zu der Elekwicklungen,

Primärwicklung der ersten Luftspule, gen der Elektrizitätsleitung (12) und der schen einer der Stromversorgungsleitunren miteinander parallelgeschaltet sind zwi-

Elektrizitätsleitung (12) und di 🖇 kundäranderen Stromversorgungsleitung der anschließend in Reihe geschaltet mit der die Primärwicklung der ersten Luftspule ist

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gekennzeichn t durch 30. Kommunikationseinrichtung nach Anspruch 4,

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- geschaltet sind. allel und in Reihe zu der Elektrizitätsleitung (12) die Widerstandseinrichtung (35) zueinander parstant, wobei die Kondensatoreinrichtung (34) und tung (35) aus wenigstens einem Widerstand beordnung bildet, wobei die Widerstandseinricheinem zweiten LC-Kreis (32) eine dritte LC-Anderstandseinrichtung (35), die in Kombination mit Kopplereinrichtung (22) umfaßt ferner eine Winigst ns einem Kond nsator und di zweite zweiten Kopplereinrichtung (22) besteht aus we-- die Kond nsatoreinrichtung (34) der
- die zweite Kopplereinrichtung (22) umgekennzeichnet durch 31. Kommunikationseinrichtung nach Anspruch 30,

fabt ferner eine vierte LC-Anordnung.

- gekennzeichnet durch 32. Kommunikationseinrichtung nach Anspruch 29,
- leitung (12) geschaltet. LC-Anordnung sind parallel zu der Elektrizitäts-- die erste LC-Anordnung und die zweite
- etraiv eib bnu gnunbronA-DJ etfib eib gekennzeichnet durch 33. Kommunikationseinrichtung nach Anspruch 32,
- leitung (12) geschaltet. LC-Anordnung sind parallel zu der Elektrizitäte-
- etheiv eib brung und die Vierte gekennzeichnet durch 34. Kommunikationseinrichtung nach Anspruch 32,
- leitung (12) geschaltet. LC-Anordnung sind parallel zu der Elektrizitäta-
- gekennzeichnet durch 35. Kommunikationseinrichtung nach Anspruch 14,
- trizitätsleitung (12) geschaltet. Kopplereinrichtung (14) sind parallel zu der Elek-- die beiden LC-Kreise (34, 42) der ersten
- trizitätsleitung (12) geschaltet. Kopplereinrichtung (22) sind parallel zu der Elek-- die beiden LC-Kreise (34, 42) der zweiten gekennzeichnet durch 36. Kommunikationseinrichtung nach Anspruch 14,

Revendications

- lesdits moy ns coupl urs (14, 22) comprede sortie caractéristique, ligne électrique (12), ayant une impédance des moyens coupleurs (14, 22), reliés à une Dispositif de transmission, comprenant

- därwicklung n (40, 48) als Hochpassfilter. ger (36 und 44) erzeugt wird, wirkt mit den Sekundärwicklungen (40, 48) der eisenlosen Übertrachenden Primärwicklung n (38, 46) und Sekun-di Kapazität, die zwischen d n ntspre-
- gekennzeichnet durch 23. Kommunikationseinrichtung nach Anspruch 14,
- den Kondensatoren als Bandpassfilter. und zweiten Kopplereinrichtung (14, 22) wirkt mit - die Primärwicklungen (38, 46) der ersten
- nungen über die Kondensator- und Widerstandsrichtung (14) teilen die Gleich-/Wechselspan-- die Widerstände der ersten Kopplereingekennzeichnet durch 24. Kommunikationseinrichtung nach Anspruch 14,

schaltung herab.

- Widerstandsschaltung herab. Wechselspannungen über die Kondensator- und Kopplereinrichtung (22) teilen die Gleich-- der oder die Widerstände der zweiten gekennzeichnet durch 25. Kommunikationseinrichtung nach Anspruch 14,
- tragereinrichtung (36). Pimärwicklung (38) der ersten eisenlosen Uberachwingen (pl) einrichtung - die Kondensatoren der ersten Kopplergekennzeichnet durch 26. Kommunikationseinrichtung nach Anspruch 24,
- Ubertragers (44). Pimärwicklung (46) des zweiten eisenlosen schwingen (ZZ)einrichtung **16b Jim** - die Kondensatoren der zweiten Kopplergekennzeichnet durch 27. Kommunikationseinrichtung nach Anspruch 24,
- gekennzeichnet durch 28. Kommunikationseinrichtung nach Anspruch 1,
- trizitätsleitung (12) geschaltet sind. (35) zueinander parallel und in Reihe zu der Elekeinrichtung (34) und die Widerstandseinrichtung nem Widerstand besteht, wobei die Kondensator-Widerstandseinrichtung (35) aus wenigstens ei-(30) eine erste LC-Anordnung bildet, wobei die tung (35), die in Kombination mit dem LC-Kreis tung (14) umfaßt ferner eine Widerstandseinrichstens einem Kondensator und die Kopplereinrich-- der Kondensator (34) besteht aus wenig-
- die Kopplereinrichtung (14, 22) umfaßt gekennzeichnet durch 29. Kommunikationseinrichtung nach Anspruch 28,

ferner eine zweite LC-Anordnung.

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teuse d bande él vée présélectionnée. ligne él ctrique (12) à ladite fréquence porl'impédance de sortie caractéristique de la

- roulement primaire (38) audit enroulement se-- le rapport du nombre des spires dudit en-2, caractérisé en ce que Dispositif de transmission selon la revendication
- Dispositif de transmission selon la revendication condaire (40) est d'environ un pour un.
- la combinaison de la capacité, créée en-2, caractérisé en ce que
- haut. teur à air (36) fonctionne comme un filtre passelement secondaire (40) dudit moyen transformatre ledit enroulement primaire (38) et ledit enrou-
- 4, caractérisé en ce que 7. Dispositif de transmission selon la revendication
- formant condensateur (42), et par ment primaire (46) étant relié audit moyen syant un premier diamètre, ledit enroule-(44) comporte un enroulement primaire (46) - ledit second moyen transformateur à air
- et ledit enroulement secondaire (48). d'air entre ledit enroulement primaire (46) primaire (46) de manière à créer un espace re coaxiale à l'intérieur dudit enroulement ment secondaire (48) s'étendant de manièsecond diamètre plus petit, ledit enroule-- un enroulement secondaire (48) ayant un
- ladite fréquence de bande élevée est in-1, caractériaé en ce que 8. Dispositif de transmission selon la revendication
- 1, caractérisé en ce que 9. Dispositif de transmission selon la revendication

férieure à environ 160 KHz. - ladite fréquence de bande élevée est in-

férieure à environ 1 MHz.

- 4, caractérisé en ce que 10. Dispositif de transmission selon la revendication
- la largeur de bande. une réduction du bruit d'environ vingt décibels à et ledit second moyen coupleur (22) comporte rée en un point entre ledit moyen récepteur (26) ladite fréquence de bande élevée, mesu-
- 2, caractérisé en ce que 11. Dispositif de transmission selon la revendication
- quence porteus présél cti nné soit à peu près pour l'émission et pour la réception à une fré-(8E) enisming tnemeluone'l eb étiviteises al eup nent un moyen d'adaptation d'impédance afin - lesdites bobines à air (36, 44) compren-

caractériaé par nant un moyen transformateur (36),

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- **,eevée**, l ctionnée syant un fréquenc de band duler un signai à fréquence porteus présé-- des moyens modulateurs (20, 28) p ur mo-
- auxdits moyens coupleurs (14, 22), transmettre ledit signal à porteuse modulée dits moyens modulateurs (20, 28) pour - des moyens émetteurs (16, 24), reliés aux-
- transformateur à air, et - ledit moyen transformateur étant un moyen
- lectionnée. dneuce borteuse de bande élevée préséque de la ligne électrique (12) à ladite frépond à l'impédance de sortie caractéristiassure une impédance d'entrée, qui corresiup (0£) (èficapac de capacité) (30) qui formant condensateur (34) constituant un disposé en combinaison avec un moyen - ledit moyen transformateur à air (36) étant
- 1, caractérisé en ce que Dispositif de transmission selon la revendication
- nière coaxiale à l'intérieur dudit enroulesecond diamètre plus petit, s'étend de ma-- un enroulement secondaire (40), ayant un dit moyen formant condensateur (34), et ayant un premier diamètre et étant relié aucomprend un enroulement primaire (38) - ledit moyen transformateur à air (36)
- re et ledit enroulement secondaire. espace d'air entre ledit enroulement primaiment primaire (38), de manière à créer un
- 1, caractérisé en ce que 3. Dispositif de transmission selon la revendication
- couplage de phase par induction et par capacité. fonctionne comme un transformateur linéaire à - ledit moyen transformateur à air (36)
- 1, caractérisé en outre par Dispositif de transmission selon la revendication
- te ligne électrique (12), un second moyen coupleur (22) relié à ladi-
- ler ledit signal à fréquence porteuse présé-- un moyen démodulateur (28) pour démodu-
- signal à porteuse modulée vers ledit moyen moyen coupleur (22) pour acheminer ledit - un moyen récepteur (26), relié audit second lectionnée, et

démodulateur (28), et

un impédance d' ntrée, qui correspond à tuant un second circuit LC (32) qui assure moyen formant condensateur (42), constitransformateur à air (44) et un second nant en combinaison un second moyen - ledit second moyen coupleur (22), compre-

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à air (44), induction (46) dudit moyen transformateur électrique (12) et l'enroulement primaire à 1èl l'un à l'autr et en série entr la lign au moins un résistance, montés en paralconsistant en au moins un cond naateur et et un moyen formant résistanc (35), nent un moyen formant condensateur (34)

- signaux portés par une seconde fréquence transformateur à sir (44) afin d'émettre des lement secondaire à induction (48) dudit dit second moyen coupleur (22) de l'enrou-- le second moyen émetteur (24) est relié au-
- des signaux portés par une première fréafin de recevoir de la ligne électrique (12) n'est pas relié audit moyen émetteur (24), dit moyen transformateur à air (36), qui veau de l'enroulement secondaire (40) duandit second moyen coupleur (22) au ni-- un second moyen récepteur (18) est relié porteuse, sur la ilgne électrique (12),
- par ladite seconde fréquence porteuse. teuse et de moduler lesdits signaux portés à porter par ladite première fréquence porteur (18) afin de démoduler lesdits signaux émetteur (24) et ledit second moyen récepétant monté entre ledit second moyen - un second moyen formant modem (23), quence porteuse, et

15. Dispositif de transmission selon la revendication

teurs et une première bobine à air comprenent une première pluralité de condensacond moyens coupleurs (14, 22) compren-- lesdits circuits LC desdits premier et se-

nant des enroulements primaire et secon-

entre lesdits enroulements primaire et sesecondaire, pour ainsi créer un espace d'air supérieur au diamètre dudit enroulement - le diamètre dudit enroulement primaire est daire,

condaire,

14, caractérisé en ce que

- condensateurs sont montés ensemble en - dans lequel ladite première pluralité de dits enroulements primaire et secondaire, pour ainsi créer un espace d'air entre lesau diamètre dudit enroulement secondaire dudit enroulement primaire étant supérieur lements primaire et secondaire, le diamètre conde bobine à air, comprenant des enroucouqe bintalité de condensateurs et une seligne électrique (12) et comprend une se-- l'autre circuit LC est monté en parallèle à la
- re bobine à air, ledit enroulement primaire de ladite premièport d'énergie de la ligne électrique (12) et paralièle, entre l'une des lignes de trans-

connu d la lign électrique (12). égal à la plus p tite impédanc caractéristique

- 1, caractérisé en ce qu 12. Dispositif de transmissi n s lon la revendication
- nent à ladite fréquence porteuse présélection-- lesdits moyens coupleurs (14, 22) réson-
- leadits moyens émetteurs (16, 24) émet-1, caractérisé en ce que 13. Dispositif de transmission selon la revendication
- termédiaire desdits moyens coupleurs (14, 22). porteuse ayant une seconde fréquence, par l'intent simultanément au moins un second signal à
- ledit premier moyen coupleur (14) tions 1 à 4, caractérisé en ce que 14. Dispositif de transmission selon les revendica-
- lesdits deux circuits LC (34, 42) comprenà ladite ligne électrique (12), comprend deux circuita LC (34, 42), reliés
- montés en parallèle l'un à l'autre, condensateur et au moins une résistance, (35), chacun consistant en au moins un teur (34) et d'un moyen formant résistance composé d'un moyen formant condensanent un circuit RC (à résistance et capacité)
- (Z) audit circuit RC et à ladite ligne électrique transformateur à air (36) est relié en série ledit enroulement primaire (38) dudit moyen
- dneuce borteuse, des signaux portés par une première frétransmettre sur ladite ligne électrique (12) dit moyen transformateur à air (36) afin de veau de l'enroulement secondaire (40) dusudit premier moyen coupleur (14) au ni-- ledit premier moyen émetteur (16) est relié
- porteuse, gnaux portés par une seconde fréquence recevoir de la ligne électrique (12) des sipas relié audit moyen émetteur (16), afin de moyen transformateur à air (44), qui n'est veau de l'enroulement secondaire (48) du audit premier moyen coupleur (14) au ni-- ledit premier moyen récepteur (26) est relié
- ladite seconde fréquence porteuse, et de démoduler lesdits signaux portés par ter par ladite première fréquence porteuse teur (26) afin de moduler des signaux à porémetteur (16) et ledit premier moyen récepétant monté entre ledit premier moyen - un premier moyen formant modem (21),
- comprend deux circuits LC (34, 42), reliés - ledit second moyen coupleur
- lesdits d ux circuits LC (34, 42) comprenà ladite ligne électrique (2),

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condair (48) dans ledit s cond may n transformat ur à air (44) est d'environ un pour un.

- 22. Dispositif d transmission selon la revendication
 14, caractérisé en ce que
 la capacité créée entre les enroulements
 primaires (38, 46) et les enroulements secondaix
 res (40, 48) respectifs desdits transformateurs à
- primaires (38, 46) et les enroulements secondaires (40, 48) respectifs desdits transformateurs à sir (36 et 44) fonctionne comme un filtre passehaut, avec les enroulements secondaires (40, 48).
- 23. Dispositif de transmission selon la revendication 14, caractérisé en ce que les enroulements primaires (38, 46) des-
- dita premier et second moyens coupleurs (14, 22), avec lesdits condensateurs, fonctionnent comme un filtre passe-bande.
- 24. Dispositif de transmission selon la revendication
 14, caractérisé en ce que
 lesdites résistances du premier moyen
- coupleur (14) divisent les tensions alternatives/continues sur ledit circuit à condensateur et à résistance.
- 25. Dispositif de transmission selon la revendication 14, caractérisé en ce que coupleur (22) divise(nt) les tensions alter-
- natives/continues sur ledit circuit à condensateur et à résistance.
- 26. Dispositif de transmission selon la revendication24, caractérisé en ce quelesdits condensateurs du premier moyen
- coupleur (14) résonnent avec l'enroulement primaire (38) dudit premier moyen transformateur à air (36).
- 27. Dispositif de transmission selon la revendication 24, caractérisé en ce que
- lesdits condensateurs du second moyen coupleur (22) résonnent avec l'enroulement primaire (46) dudit second transformateur à sir (44).
- 28. Dispositif de transmission selon la revendication 1, caractérisé en ce que
- ledit condensateur (34) consiste en au moins un condensateur et en ce que ledit moyen coupleur (14) comprend en outre un moyen formant résistance (35) qui, en combinaison avec le-dit circuit LC (30), constitue un premier moyen tot circuit LC (30), constitue un premier moyen formant résistance (35) consistant en au moins une résistance, ledit moyen formant condensateur (34) et ledit moyen formant résistance (35) étant montés en parallèle l'un à l'autre et en série avec ladite ligne électrique l'autre et en série avec la ledit moyen formant condensateur (35).

- ledit enroulement primaire d ladit première bobine à air étant ensuite relié en séri à l'autr ligne d transport d'énergie de ladite ligne électrique (12), et ledit nroul ment secondaire d ladite première bobin à air étant relié à son moyen émetteur correspondant, et
- dans lequel ladite seconde pluralité de condensateurs sont montés ensemble en série entre ladite une des lignes de transport d'énergie de ladite ligne électrique (12) et ledit enroulement primaire de ladite seconde bobine à sir, ledit enroulement primaire de ladite semaire de ladite seconde bobine à sir, ledit enroulement primaire de ladite seconde bobine à sir étant maire de ladite seconde bobine à sir étant ensuite relié en série à l'autre ligne de
- 16. Dispositif de transmission selon la revendication 14, caractérisé en ce que

transport d'énergie.

- lesdita premier et second moyens coupleurs (14, 22) ont chacun une largeur de bande inférieure à environ 200 KHz.
- 17. Dispositif de transmission selon la revendication 14, caractérisé en ce que
- leadita premier et second moyens coupleurs (14, 22) ont chacun une largeur de bande inférieure à environ 20 KHz.
- 18. Dispositif de transmission selon la revendication 14, caractérisé par
- l'élément d'induction desdits circuits LC dans chacun desdits premier et second moyens coupleurs (14 et 22), étant caractérisé en ce qu'il comprend deux bobines d'inductance à sir (36 et 44) combinées pour fonctionner comme un transformateur à sir capacitif, qui est à couplage par formateur à sir capacitif, qui est à couplage par induction et par capacité et à déphasage linéaire.
- 19. Dispositif de transmission selon la revendication
 14, caractérisé en ce que
- les enroulements primaires et secondaires desdits premier et second moyens transformateurs à air (36, 44) fonctionnent comme un transformateur à couplage par induction et par capacité.
- 20. Dispositif de transmission selon la revendication
 14, caractérisé en ce que
- le rapport du nombre de spires dudit enroulement primaire (38) audit enroulement secondaire (40) dans ledit premier moyen transformateur à air (36) est d'environ un pour un.
- 21. Dispositif de transmission selon la revendication 14, caractérisé en ce que
- le rapport du nombre de spires dudit enroul m nt primair (46) audit enroulement se-

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29. Dispositif de transmission selon la revendication 28, caractérisé en ce qu - lesdits moyens coupleurs (14, 22) comprennent n outr un second moy n LC.

30. Dispositif de transmission selon la revendication

- ledit moyen formant condensateur (34)
 dudit second moyen coupleur (22) consiste en au
 moins un condensateur, et en ce que ledit second
 moyen coupleur (22) comprend en outre un
 moyen formant résistance (35) qui, en combinaison avec un deuxième circuit LC (32) forme un
 troisième moyen LC, ledit moyen formant résistance,
 tance (35) consistant en au moins une résistance,
 ledit moyen formant condensateur (34) et ledit
 moyen formant résistance (35) étant montés en
 moyen formant résistance (35) étant montés en
- 31. Dispositif de transmission selon la revendication
 30, caractérisé en ce que
 ledit second moyen coupleur (22)
 comprend en outre un quatrième moyen LC.

parallèle l'un à l'autre et en série avec ladite ligne

électrique (12).

4, caractérisé en ce que

- 32. Dispositif de transmission selon la revendication
 29, caractérisé en ce que

 ledit premier moyen LC et ledit deuxième
 moyen LC sont reliés en parallèle à ladite ligne dectrique (12).
- 33. Dispositif de transmission selon la revendication 32, caractérisé en ce que ledit troisième moyen LC et ledit quatriè- me moyen LC sont reliés en parallèle à ladite ligne que (12).
- 34. Dispositif de transmission selon la revendication
 32, caractérisé en ce que
 ledit troisième moyen LC et ledit quatrième moyen LC sont reliés en parallèle à ladite ligne électrique (12).
- 35. Dispositif de transmission selon la revendication
 14, caractérisé en ce que
 leadita deux circuita LC (34, 42) dudit
 premier moyen coupleur (14) sont reliés en paralièle à ladite ligne électrique (12).
- 36. Dispositif de transmission selon la revendication
 14, caractérisé en ce que
 lesdits deux circuits LC (34, 42) dudit second moyen coupleur (22) sont reliés en parallèle
 à ladite ligne électrique (12).

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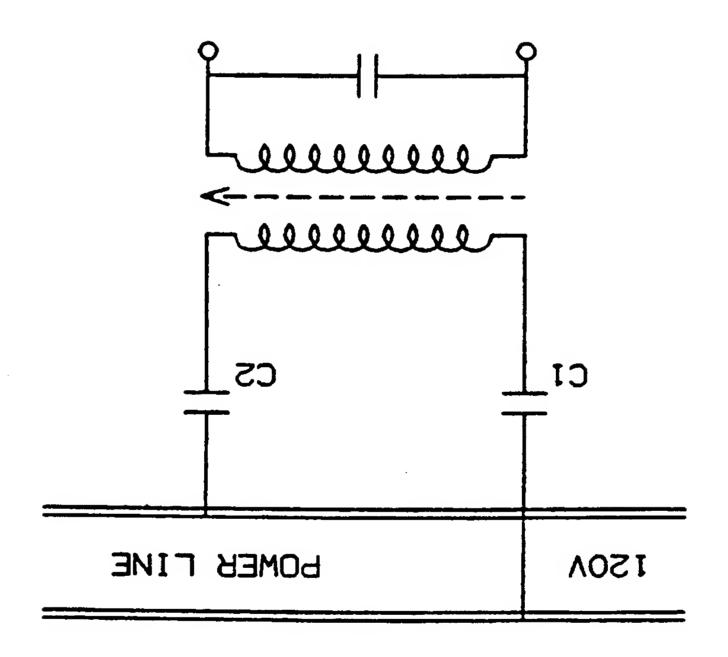
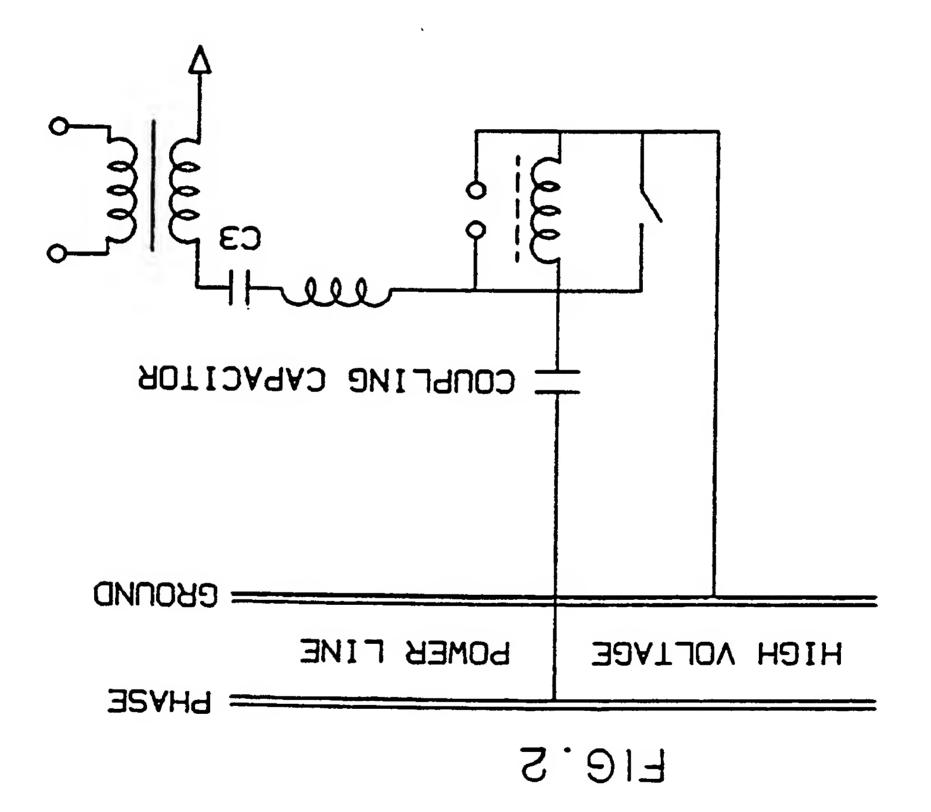
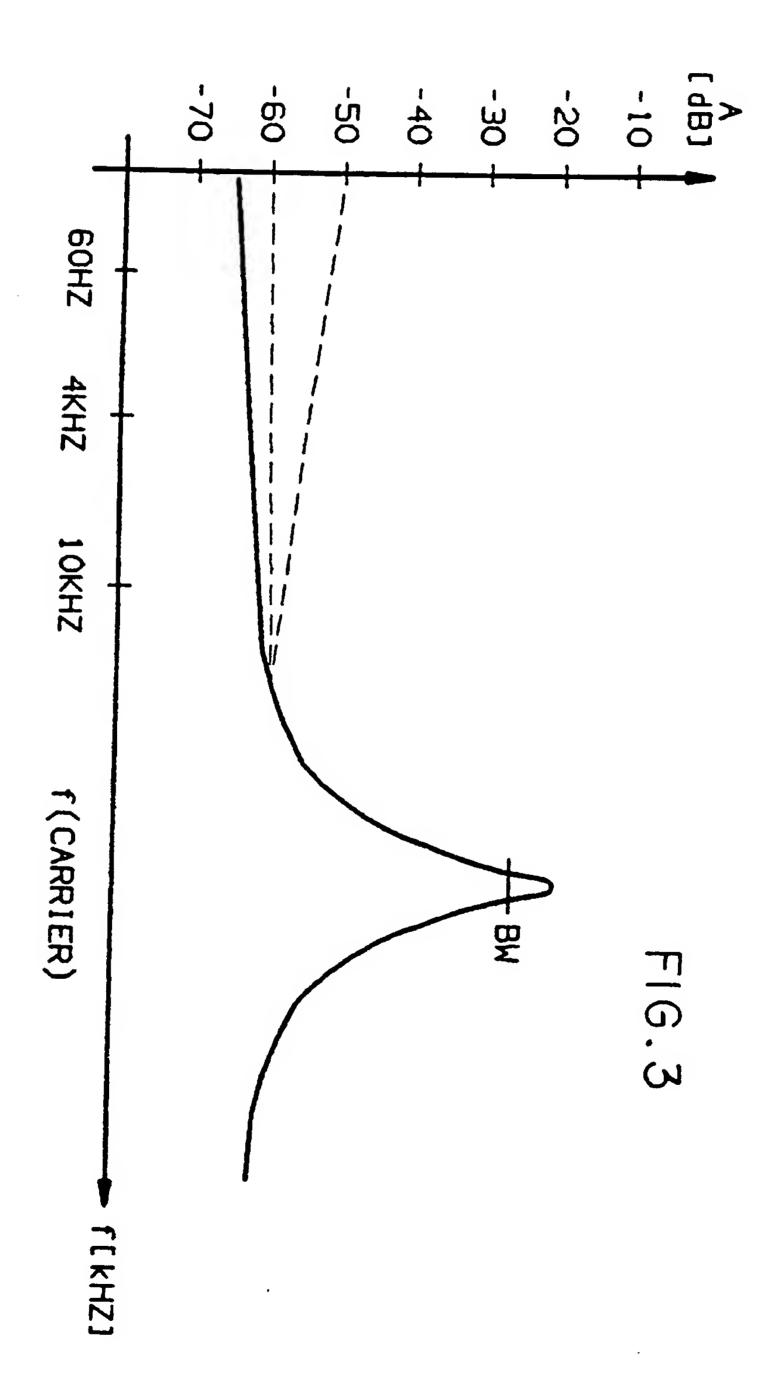


FIG.1





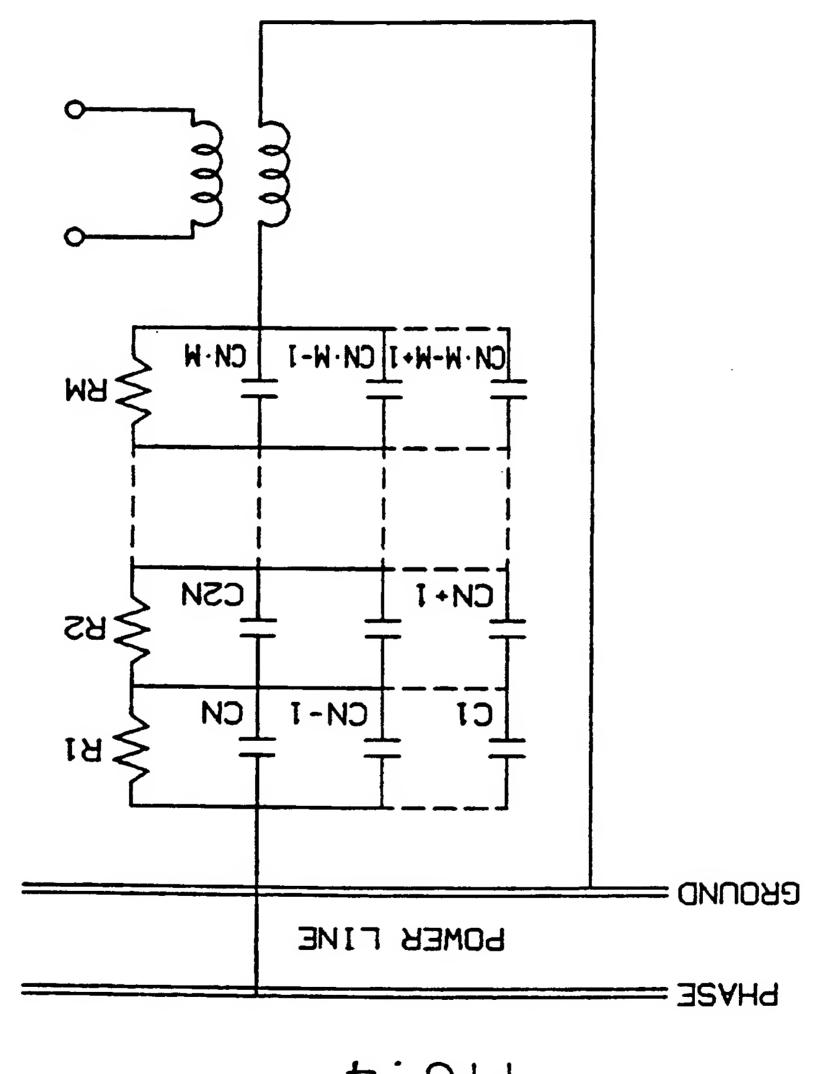
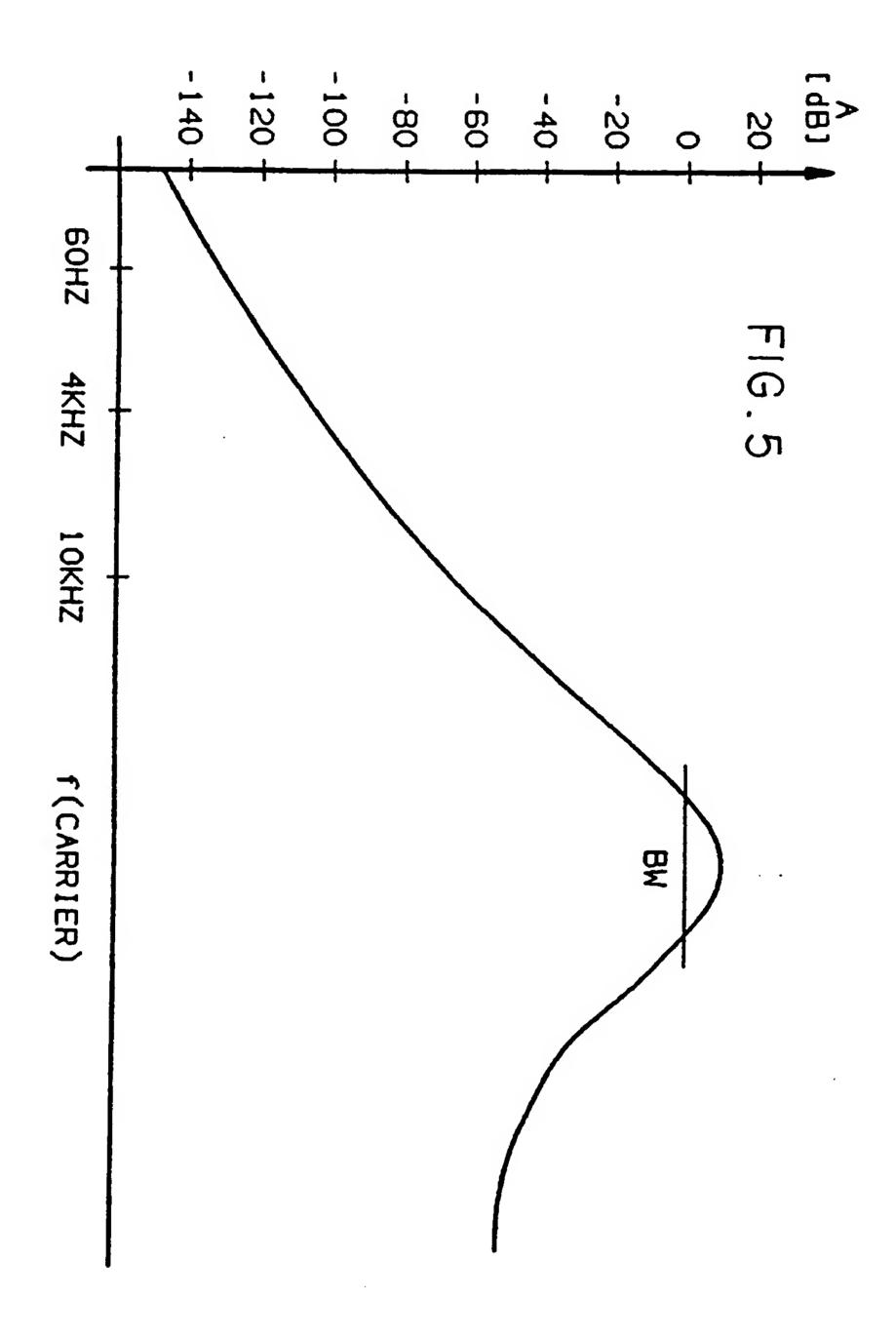
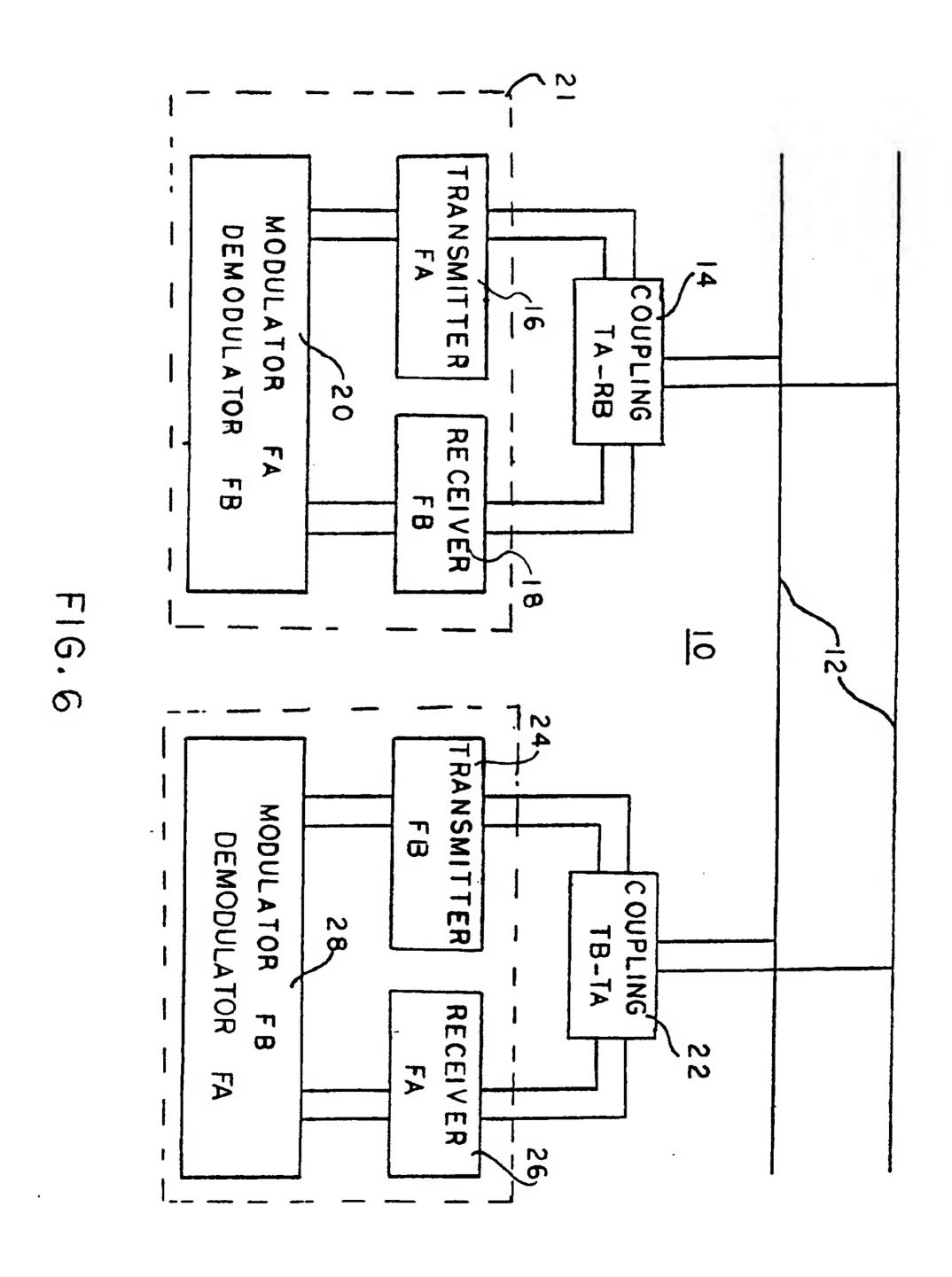
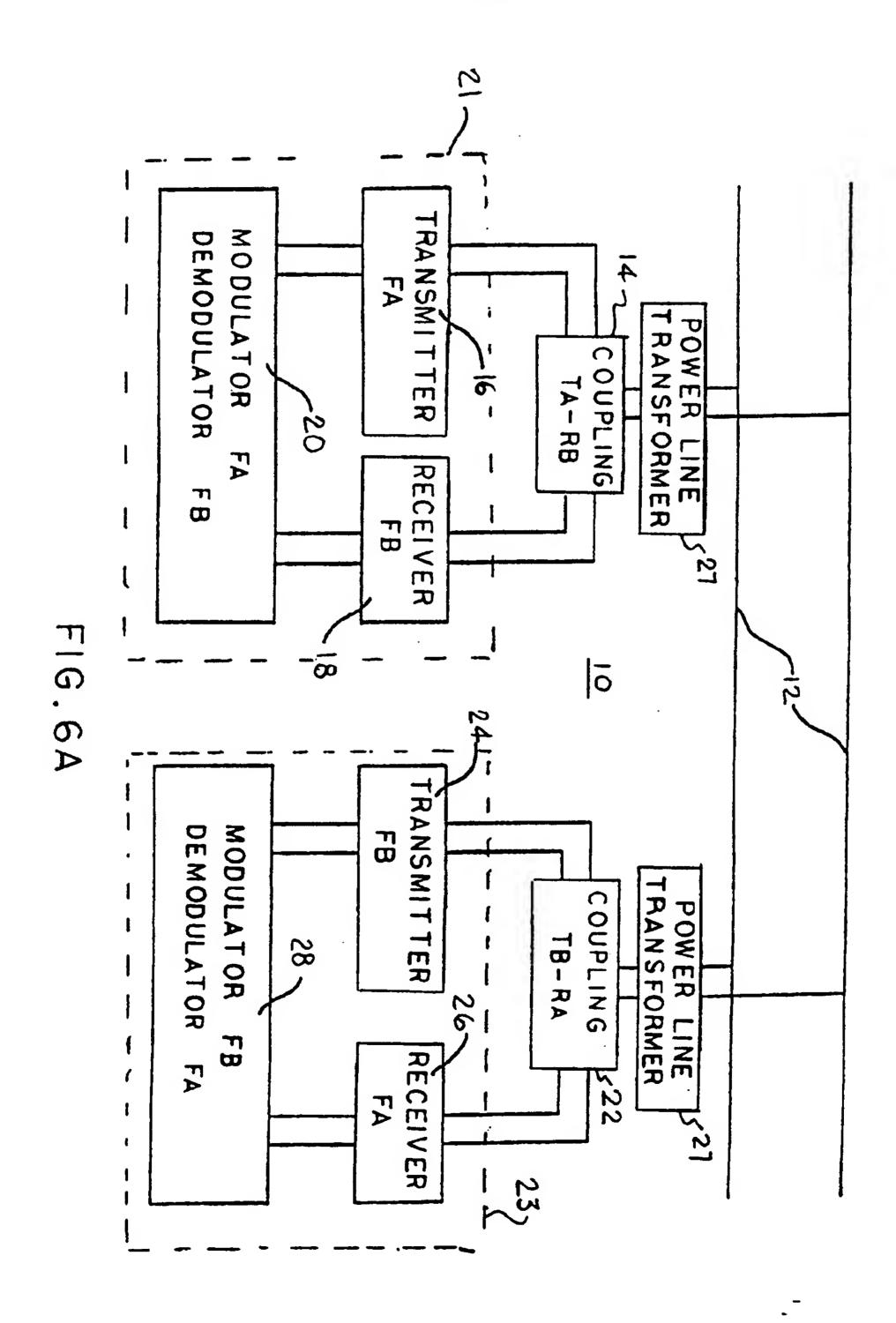


FIG.4

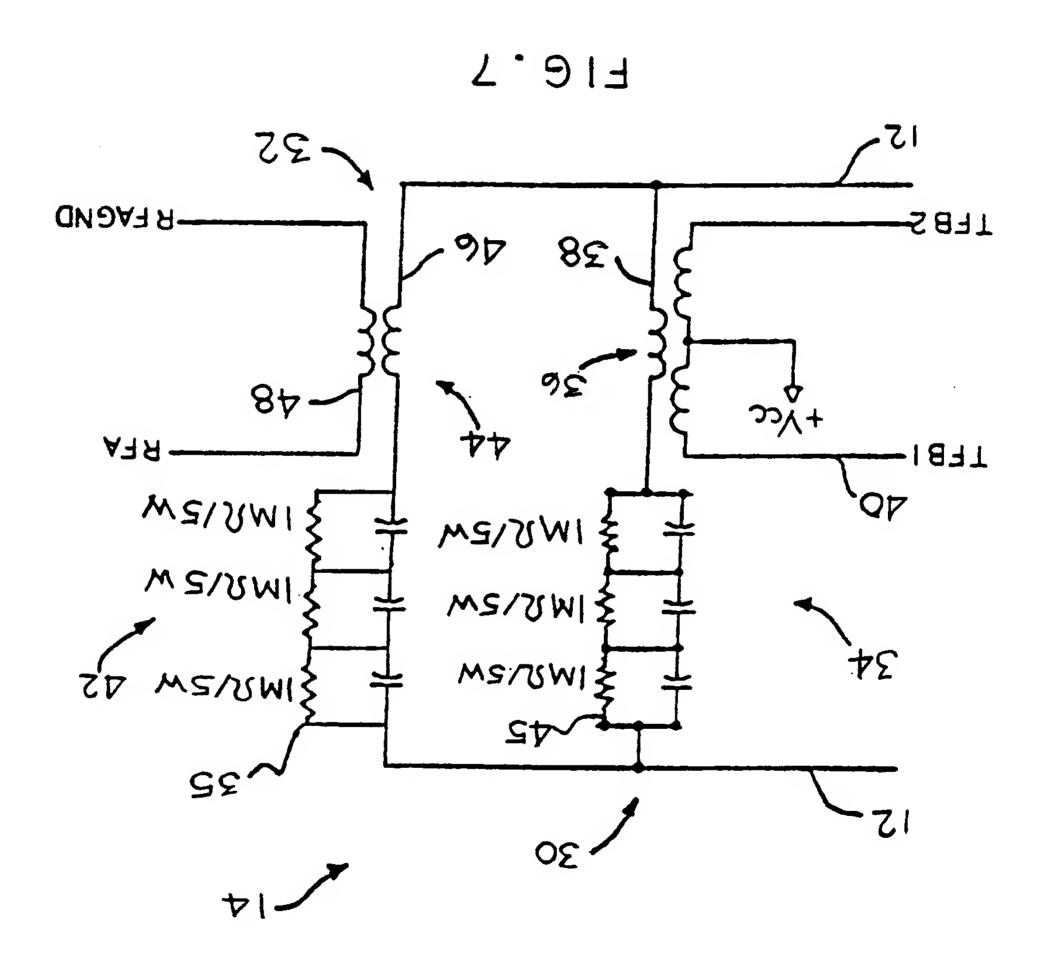


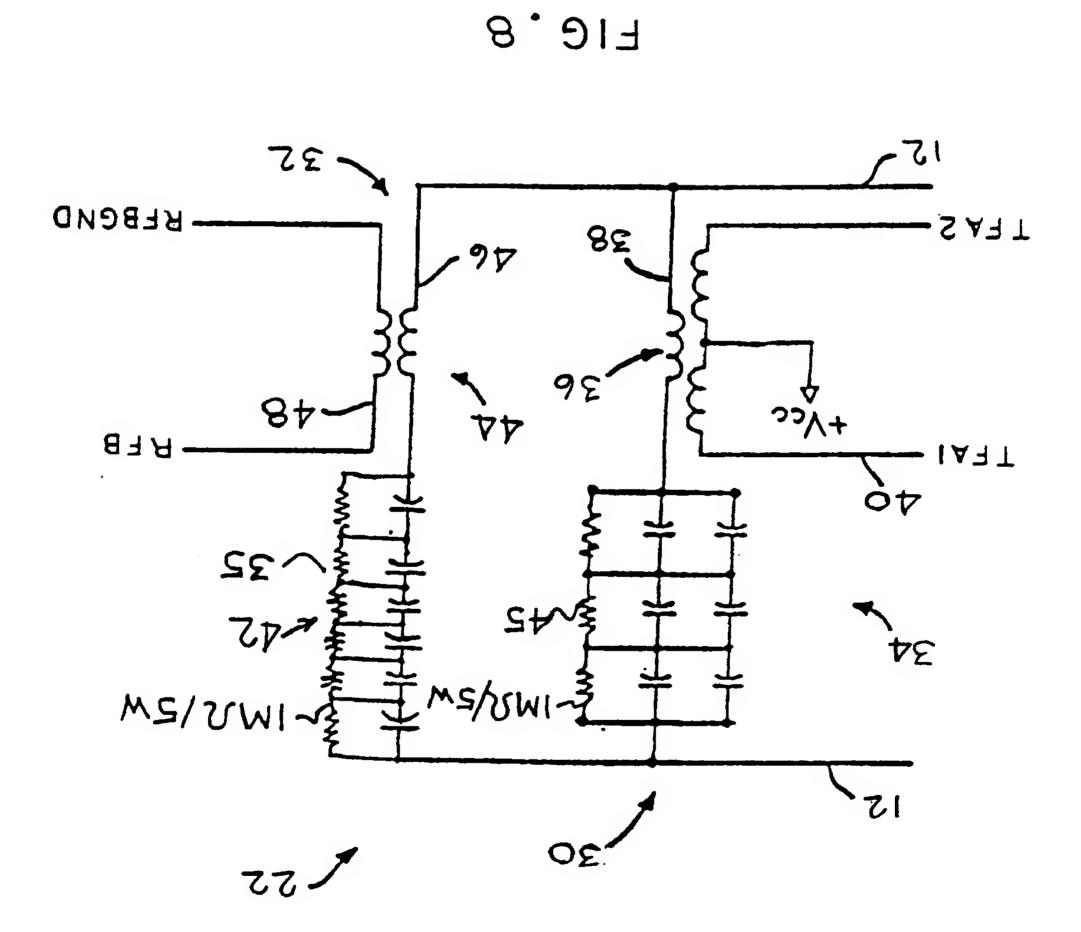


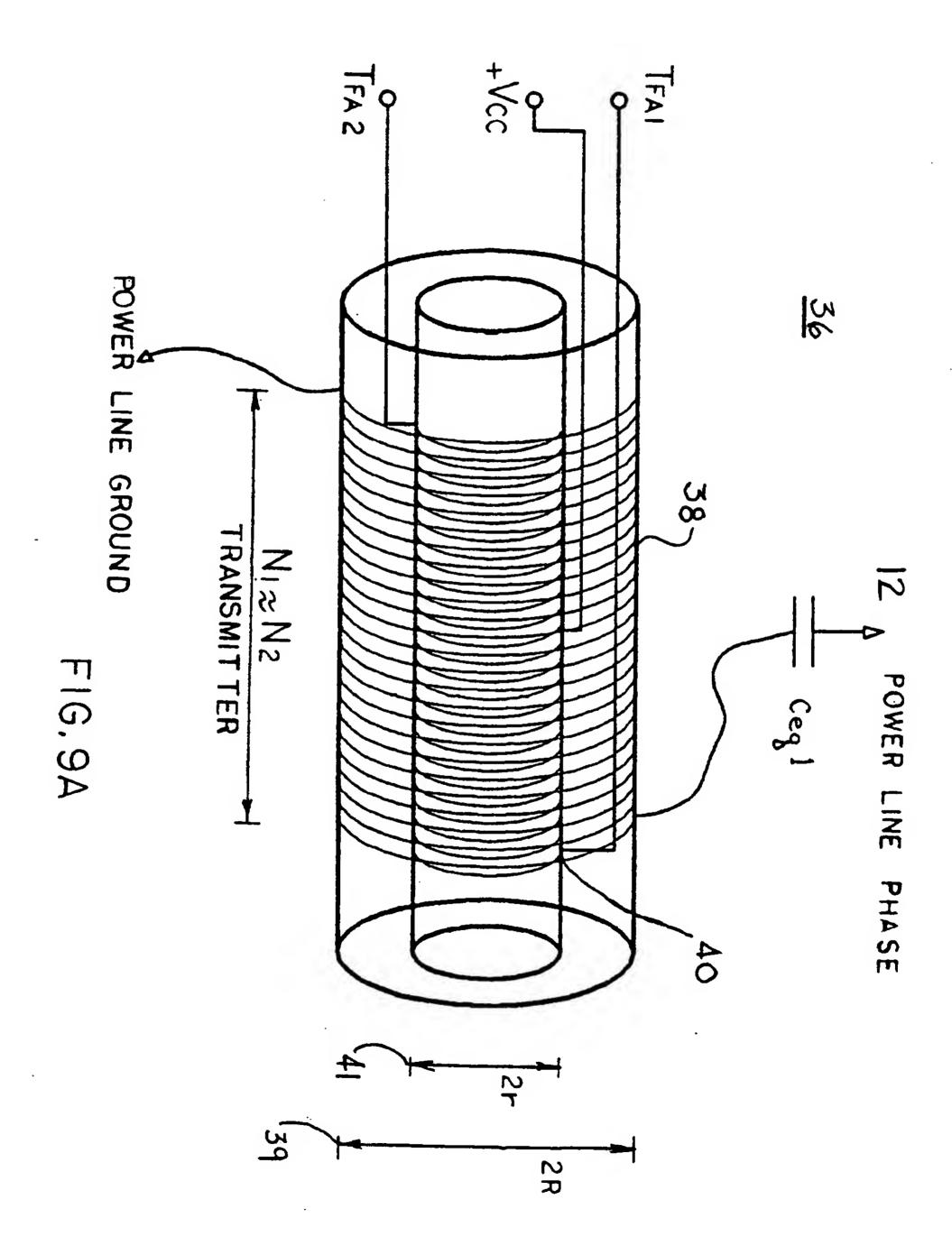
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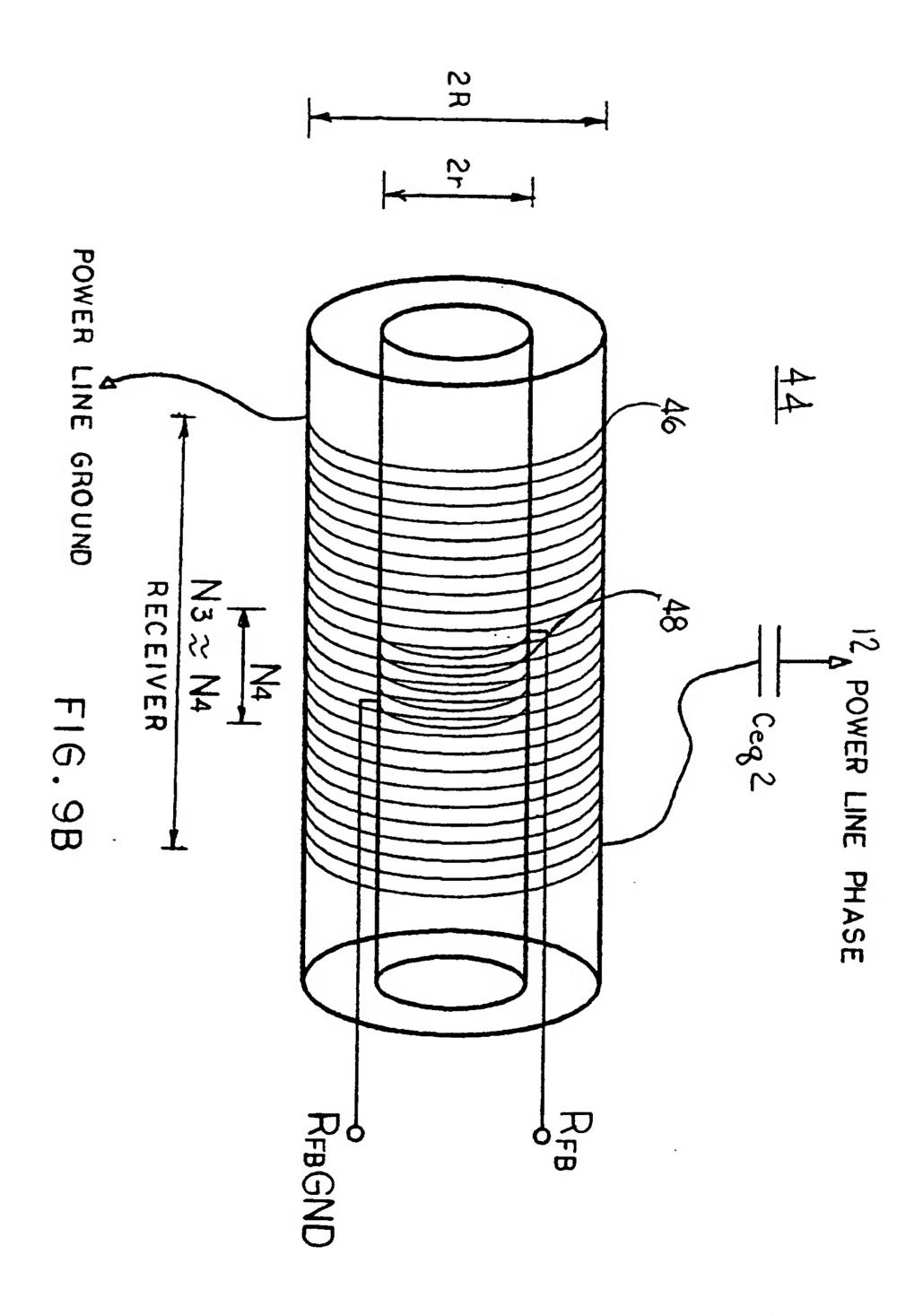
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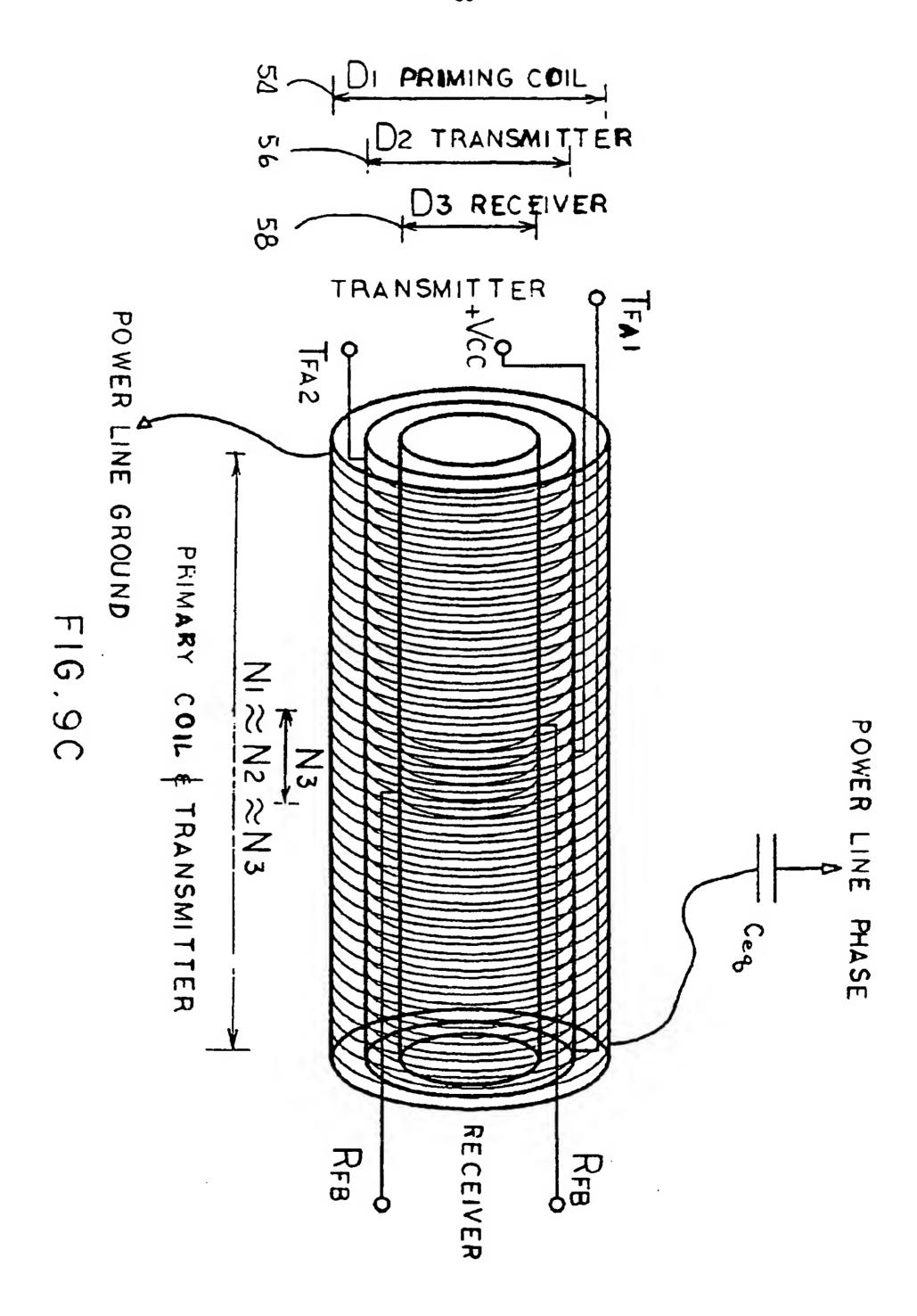


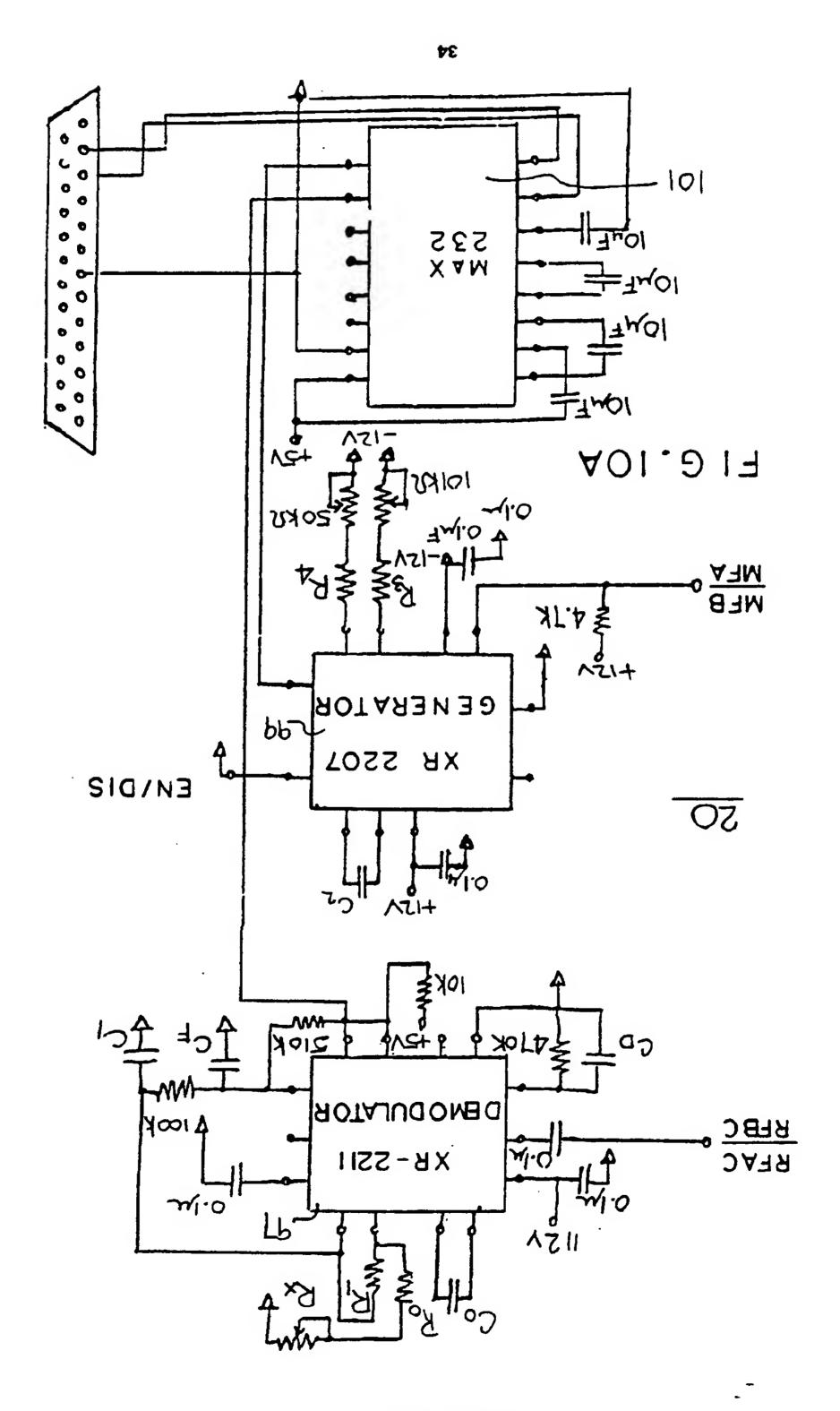


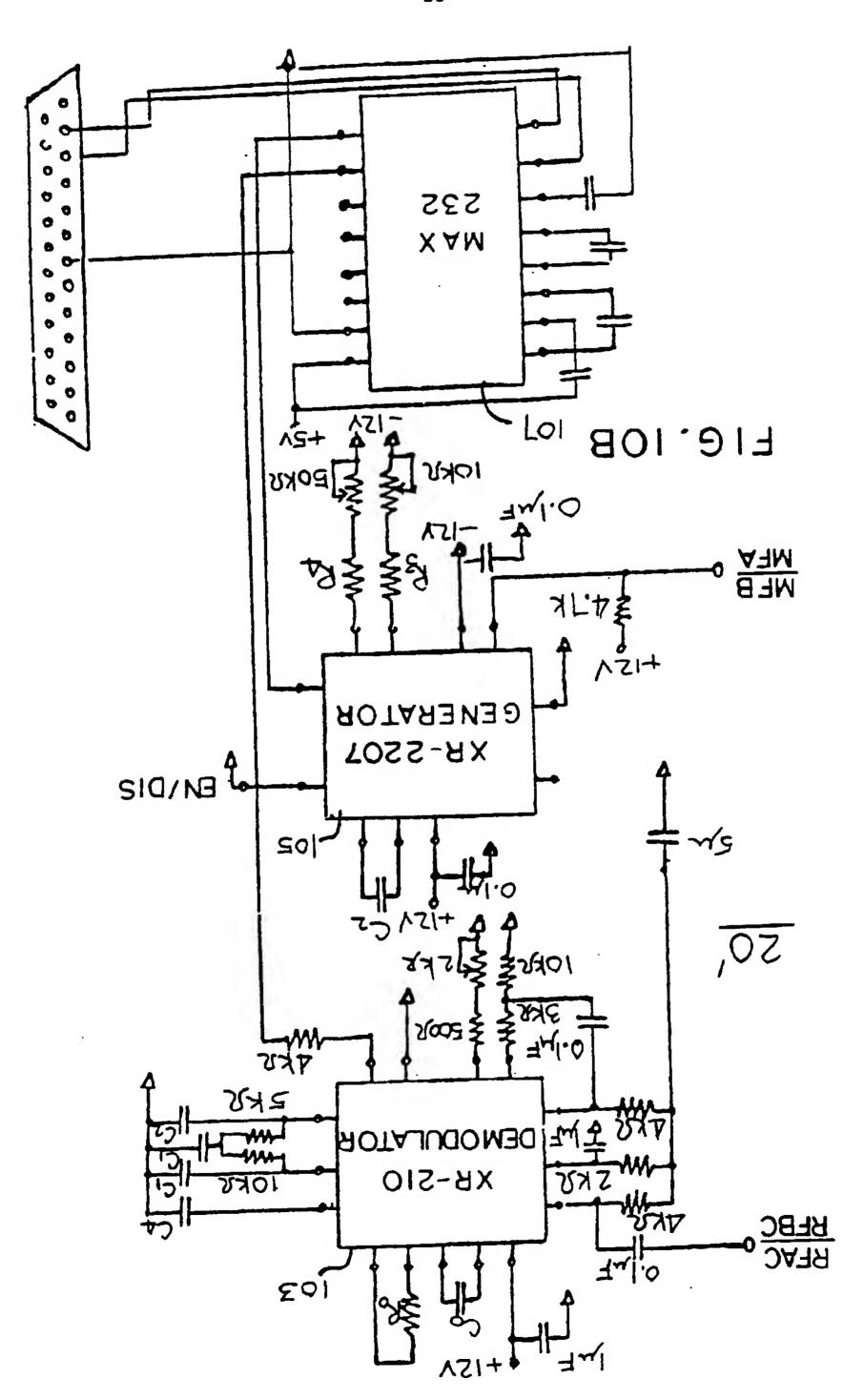


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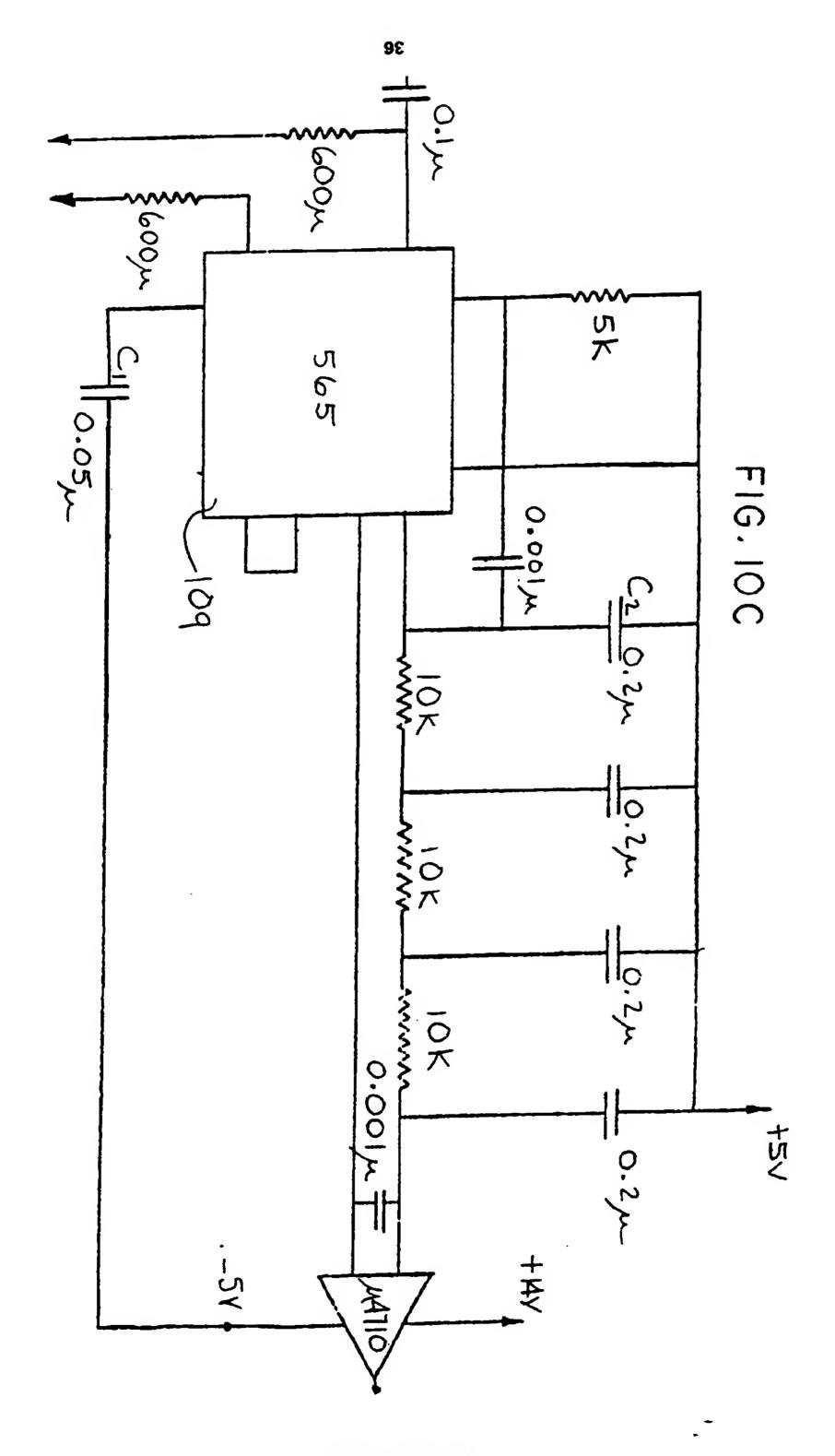




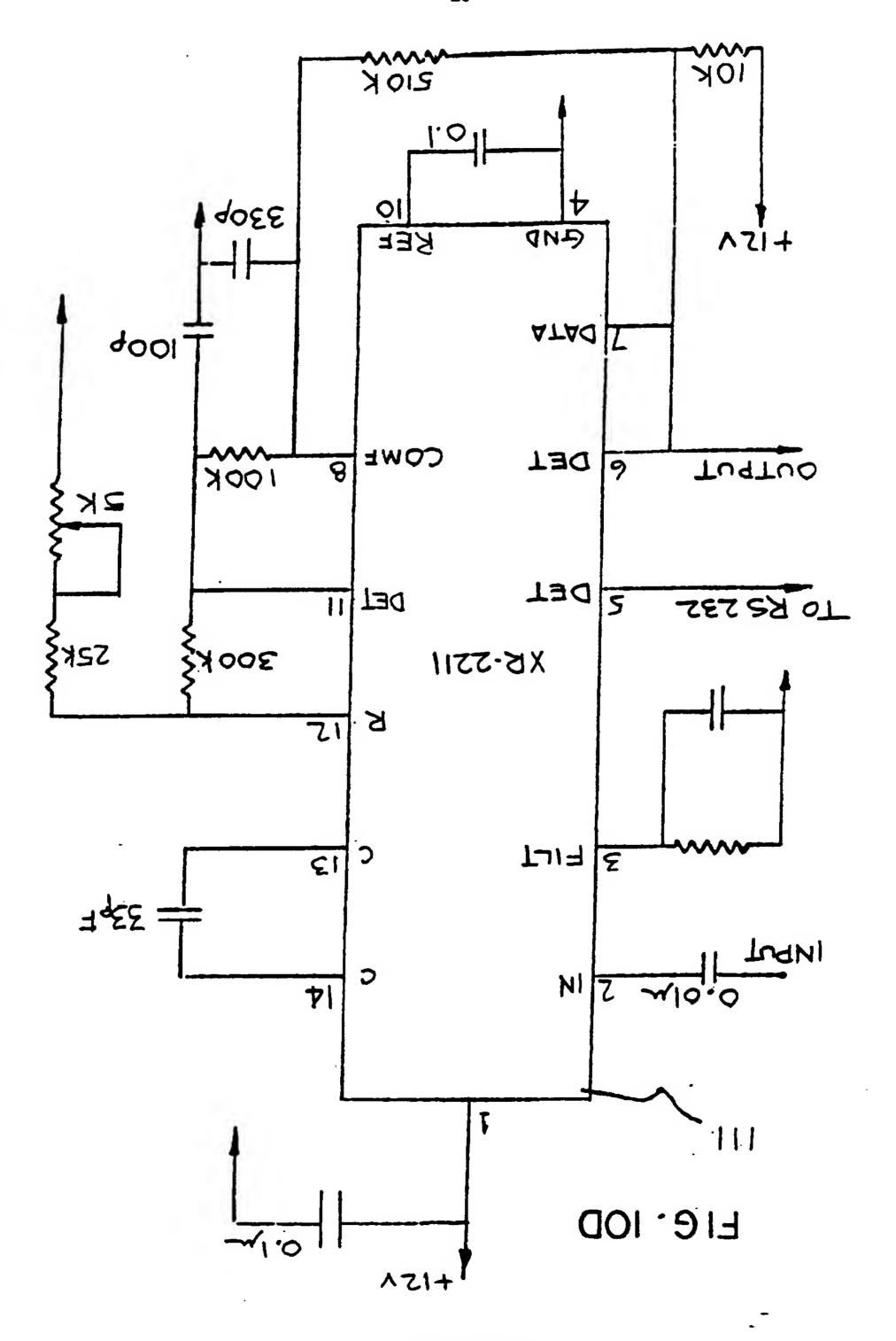




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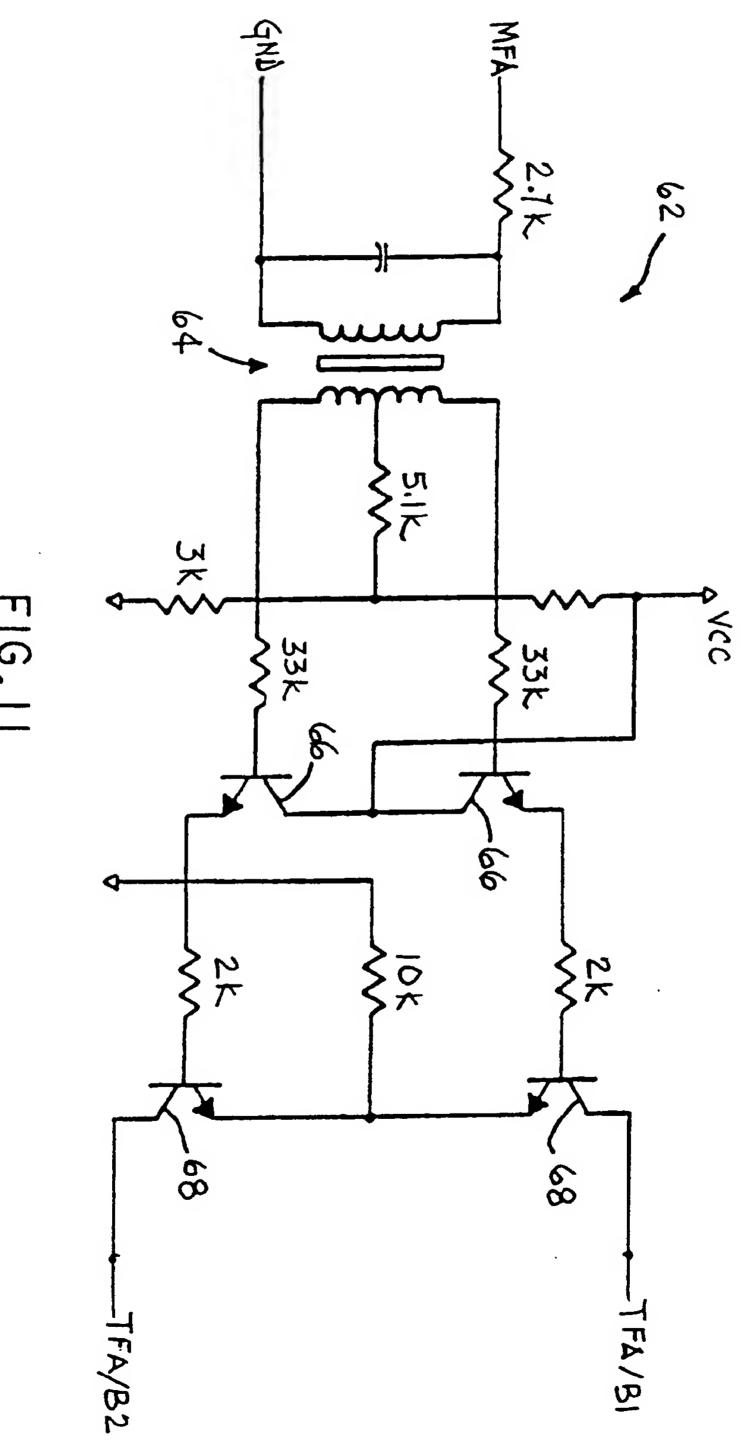


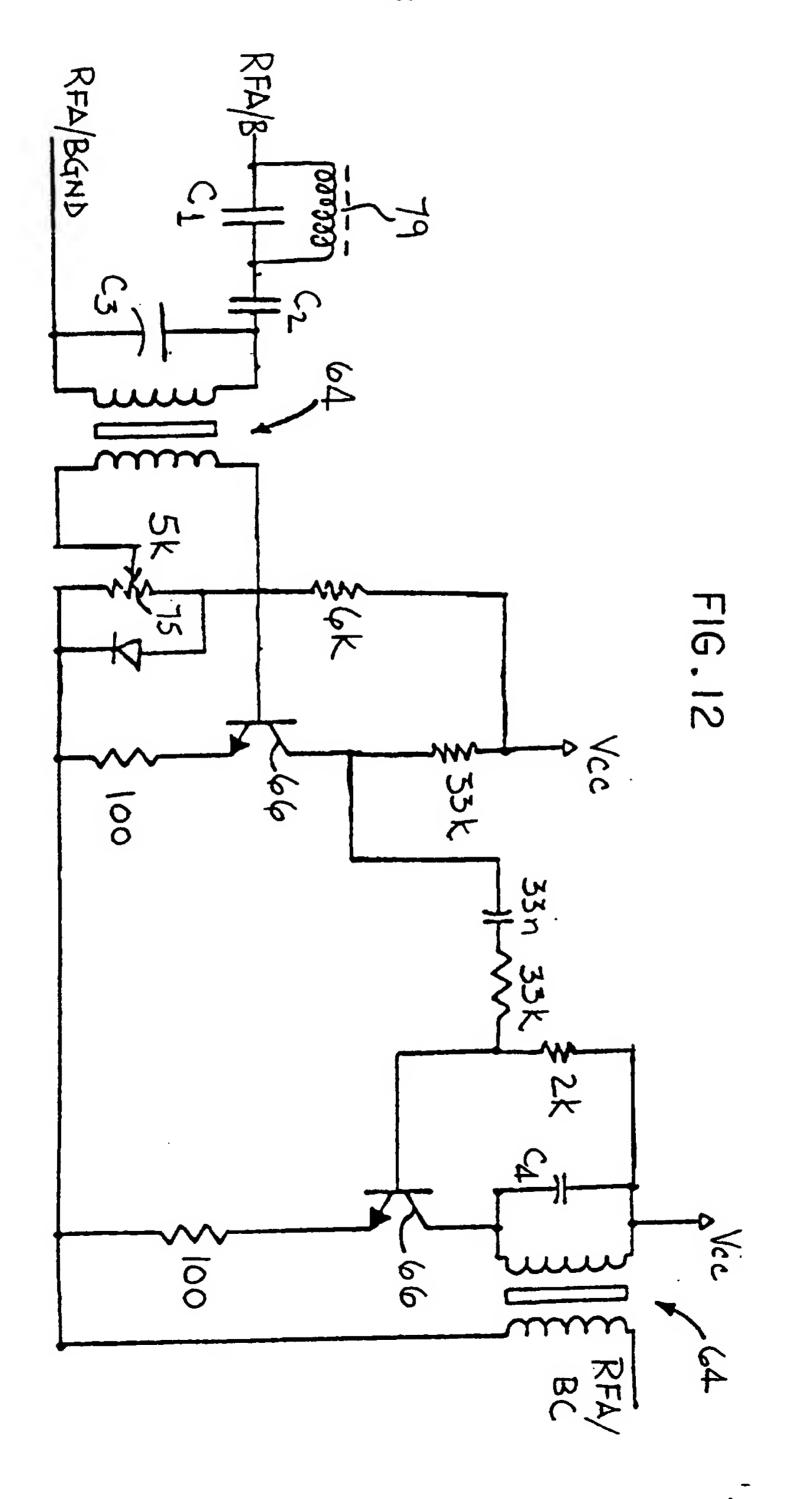
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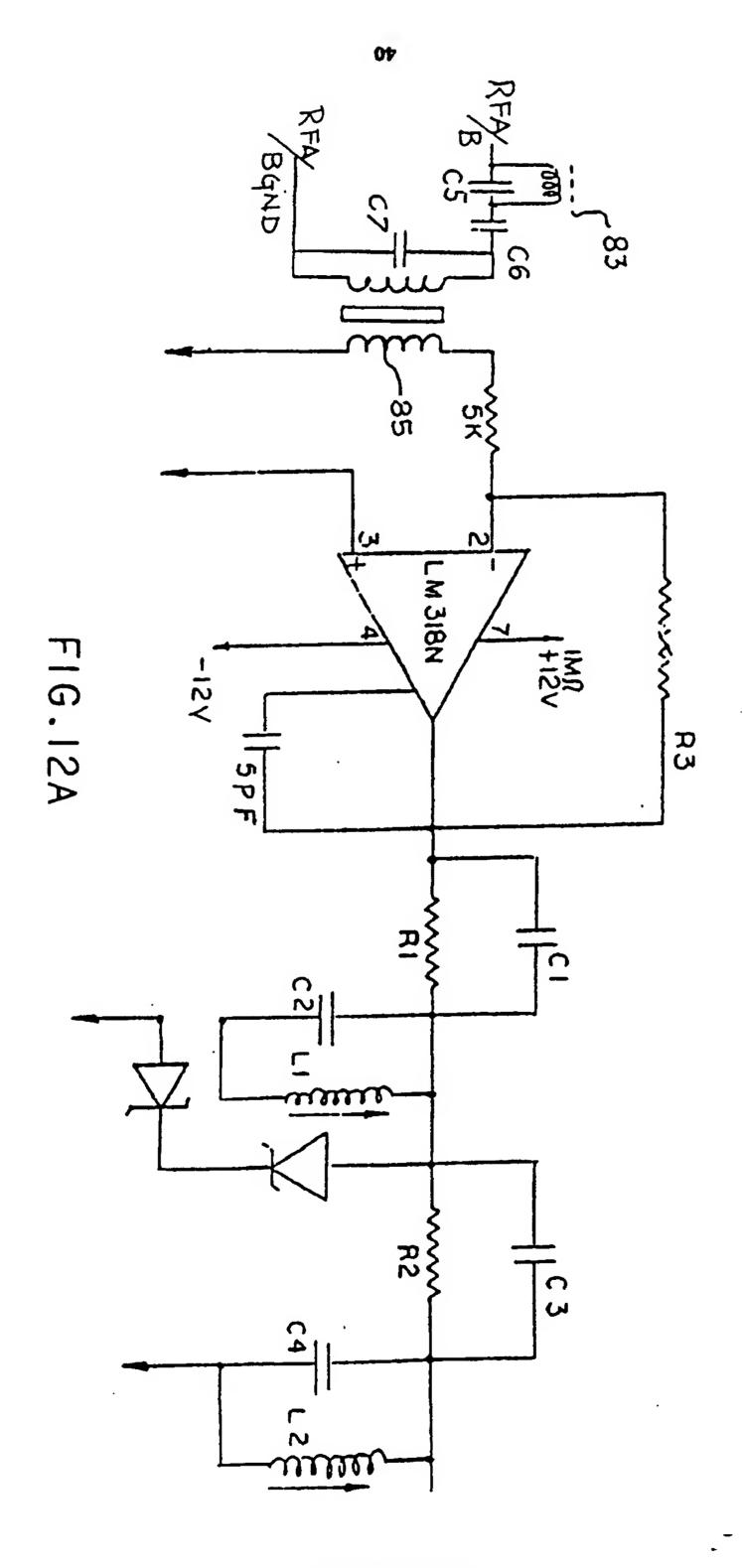
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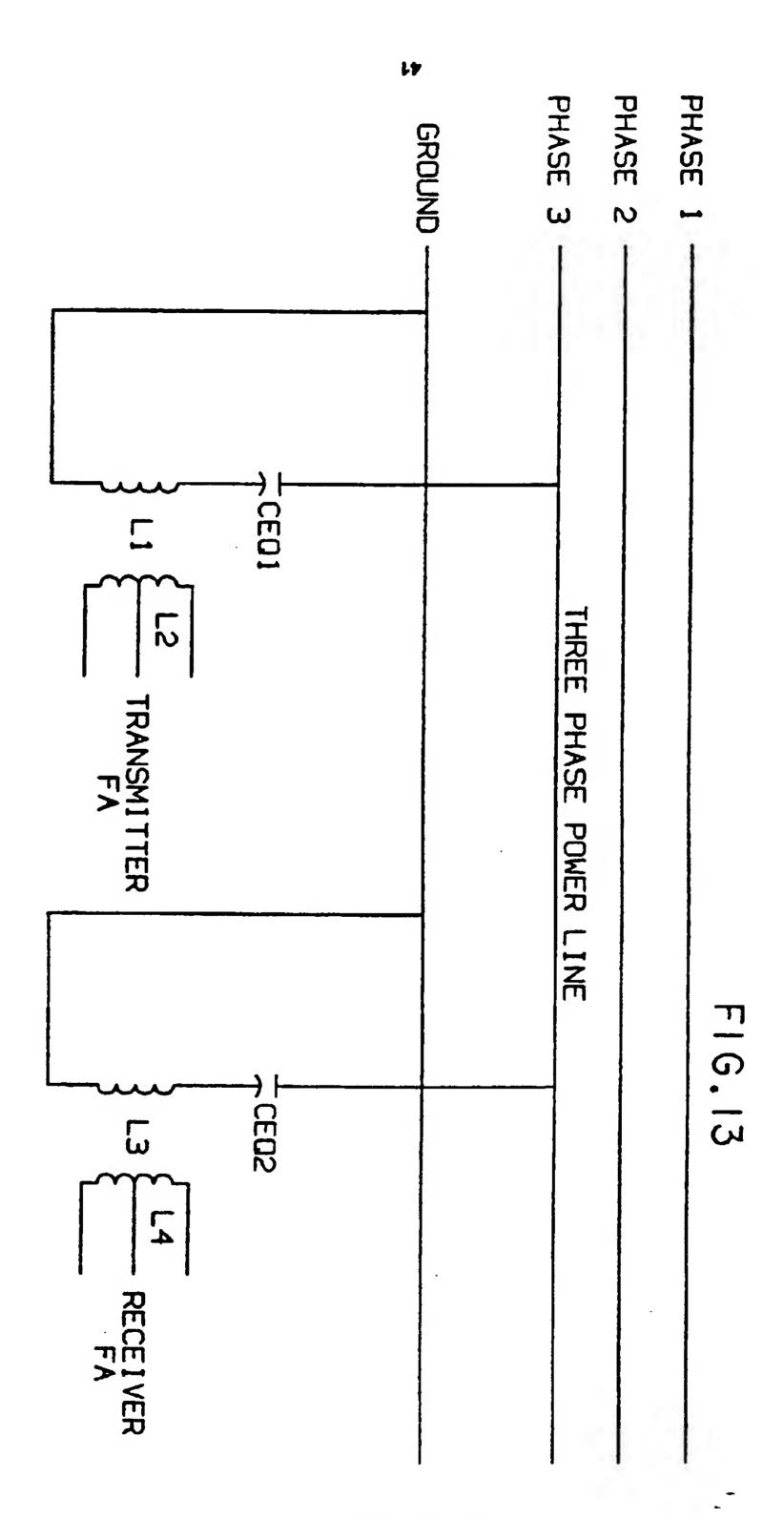




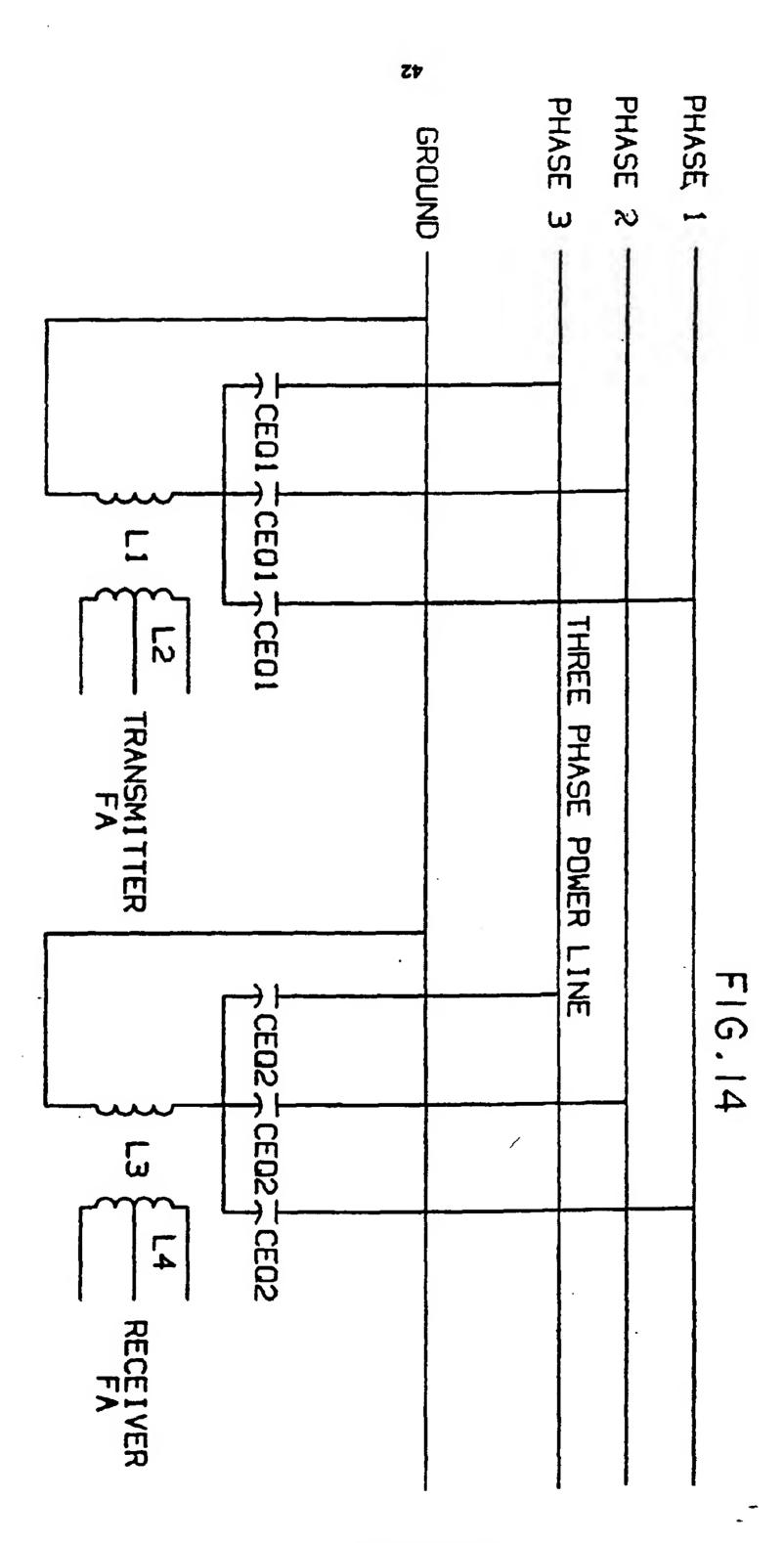
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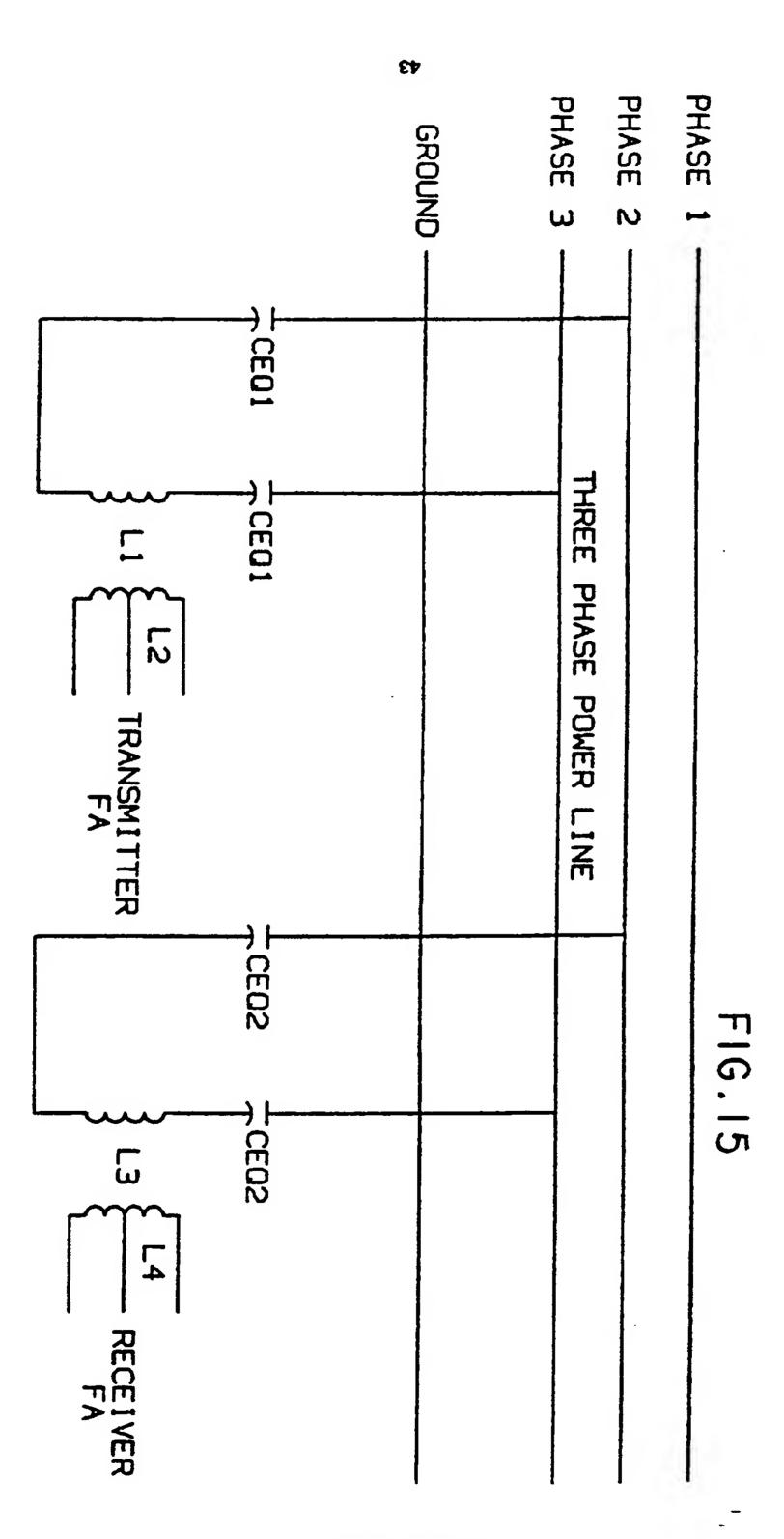
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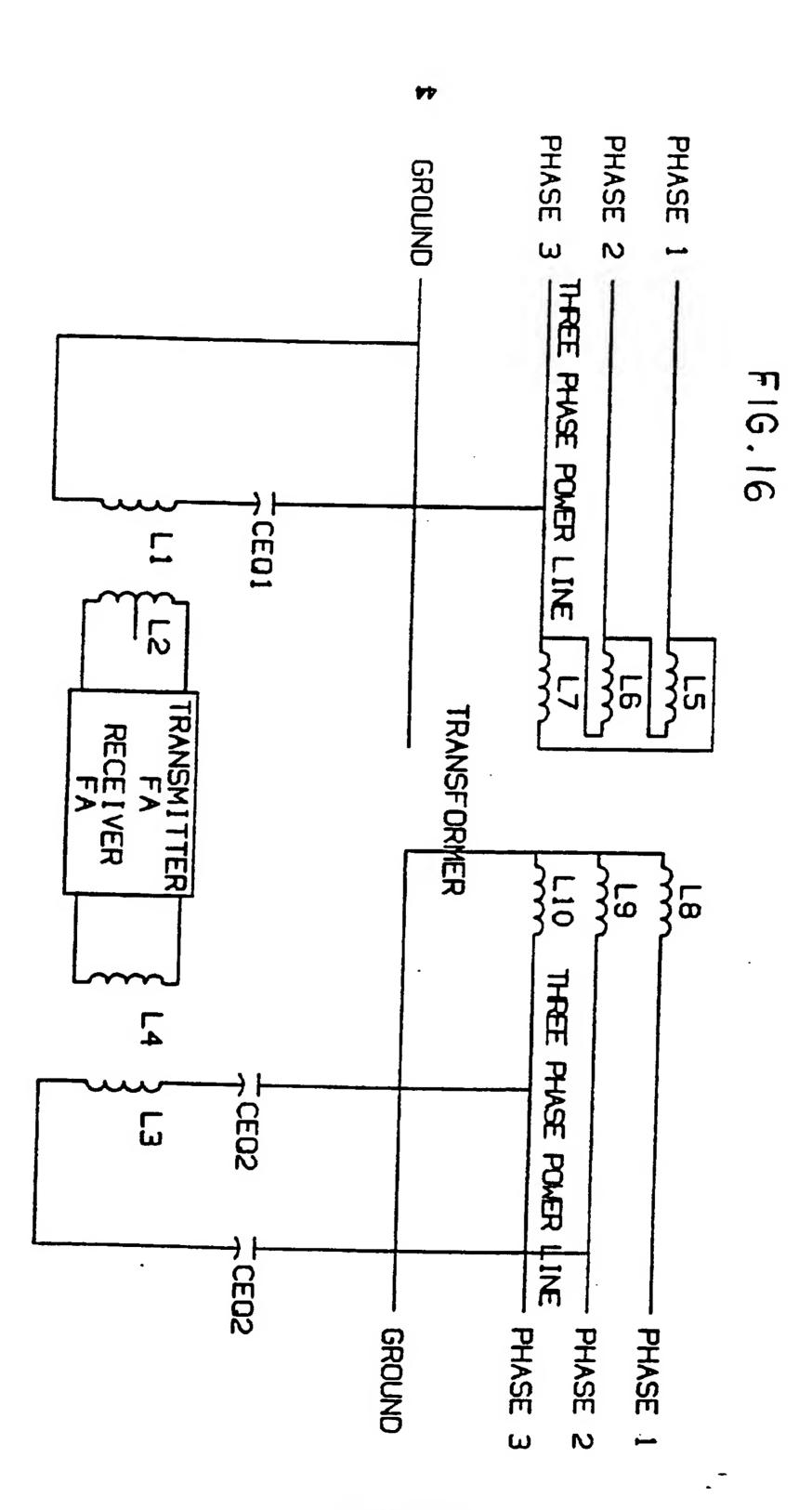
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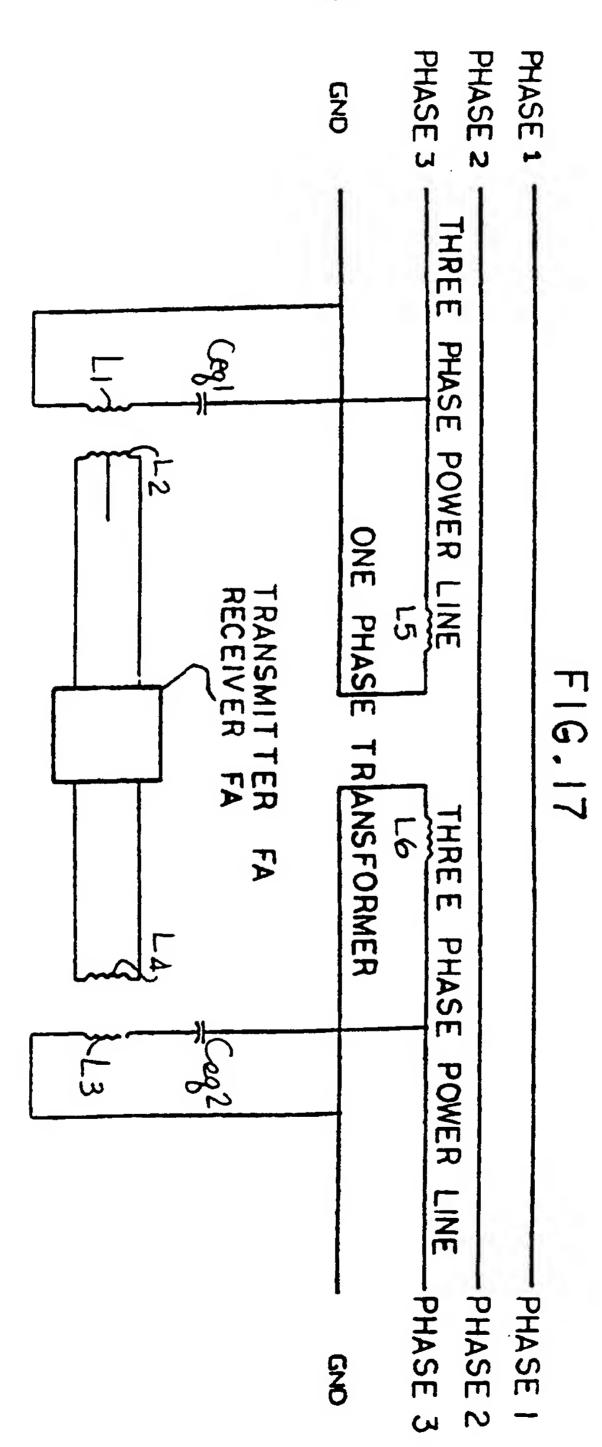


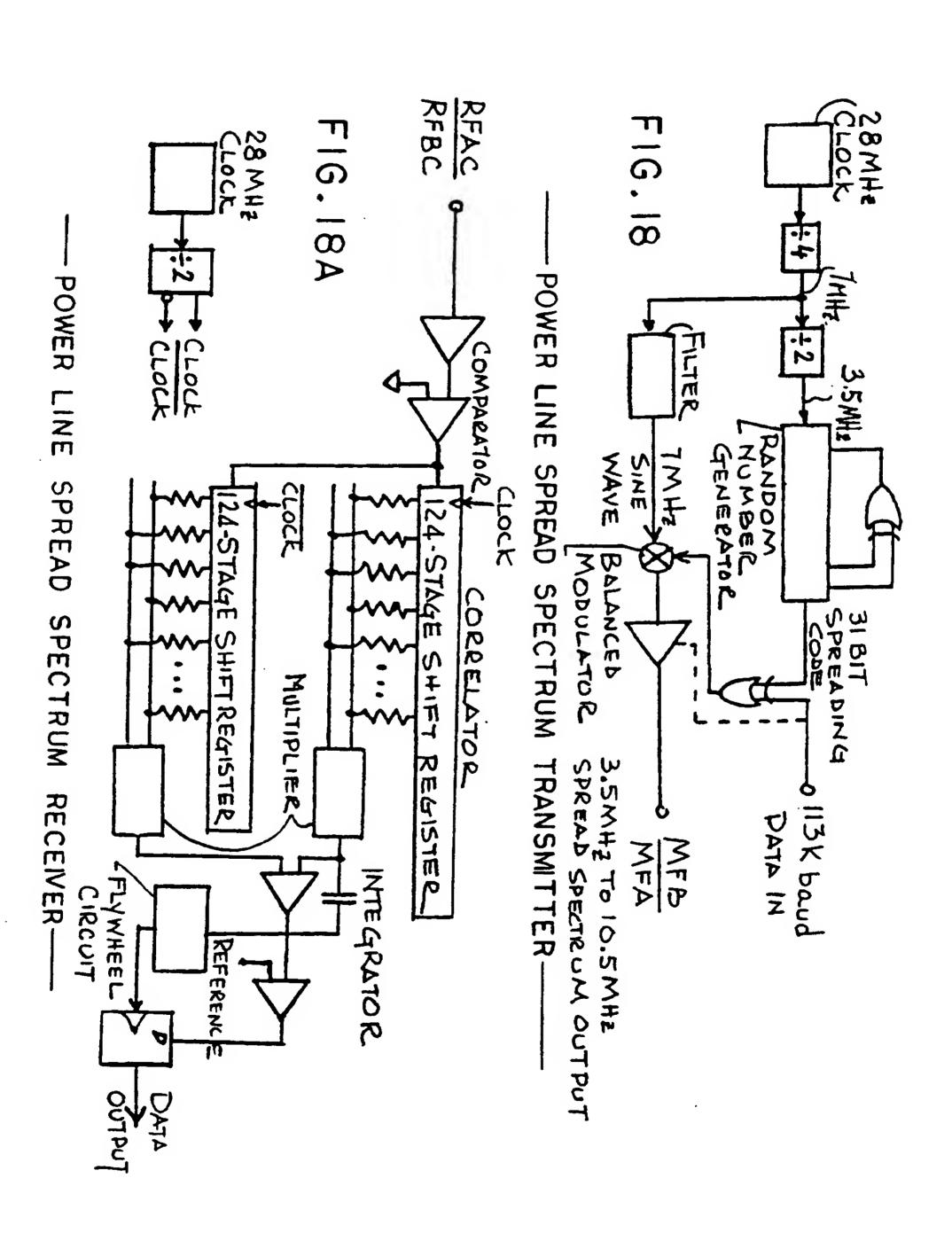
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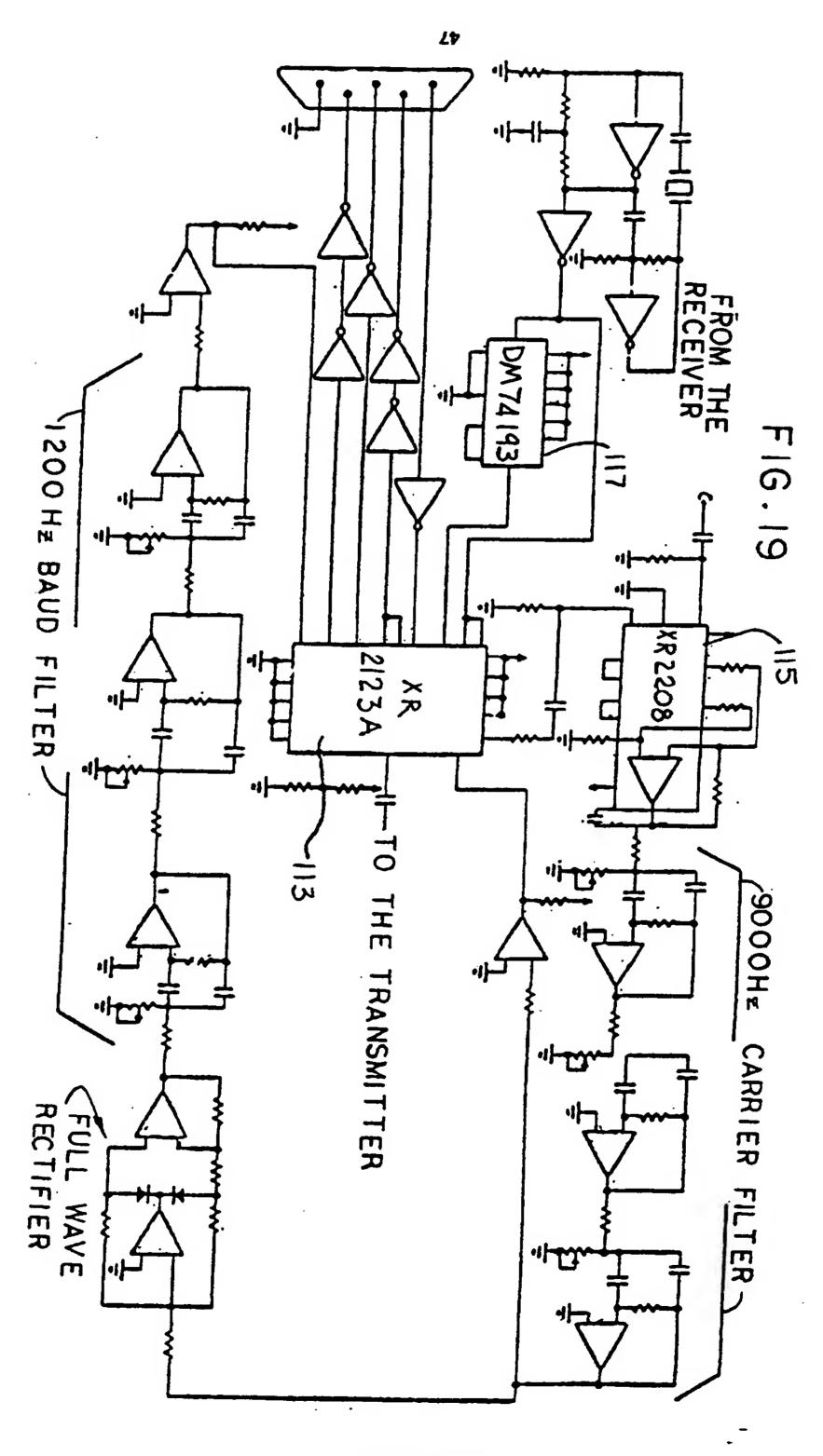


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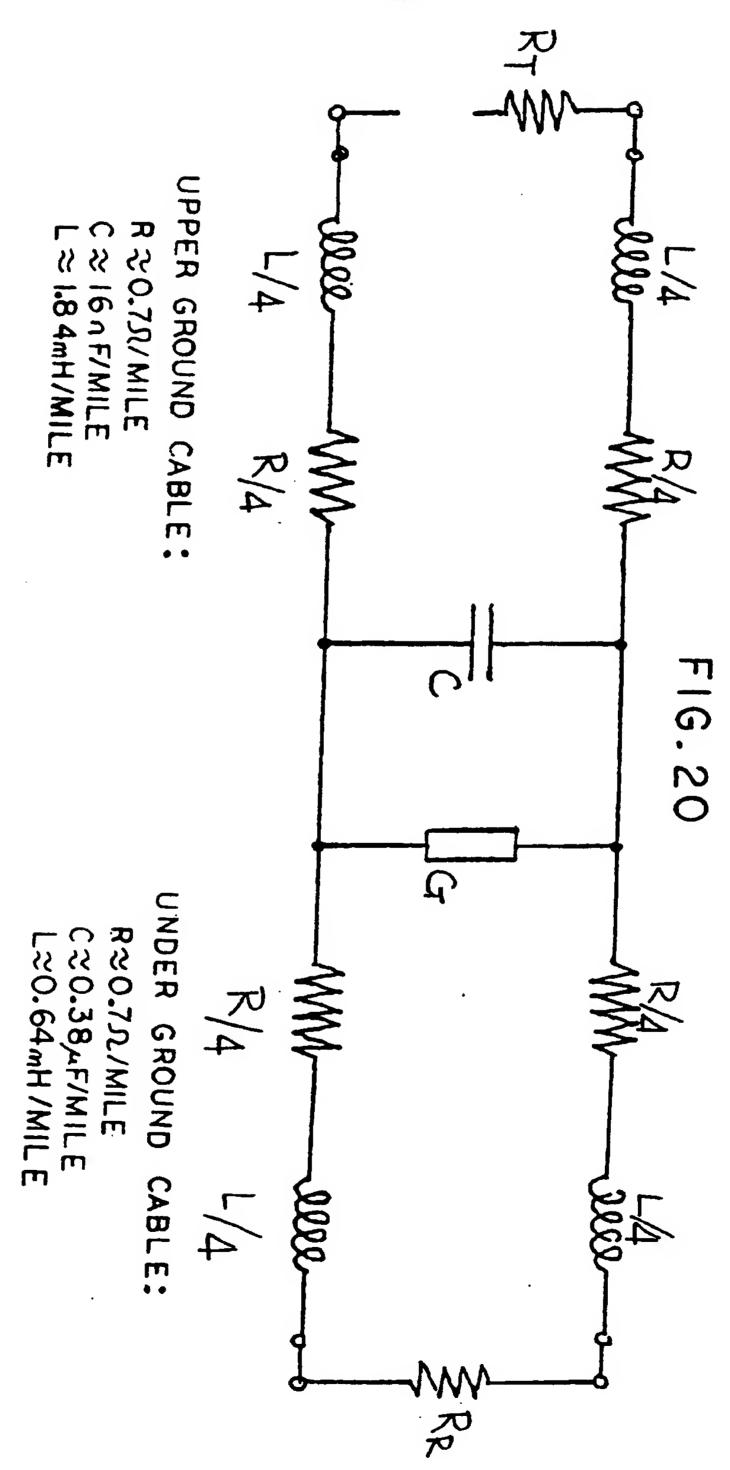




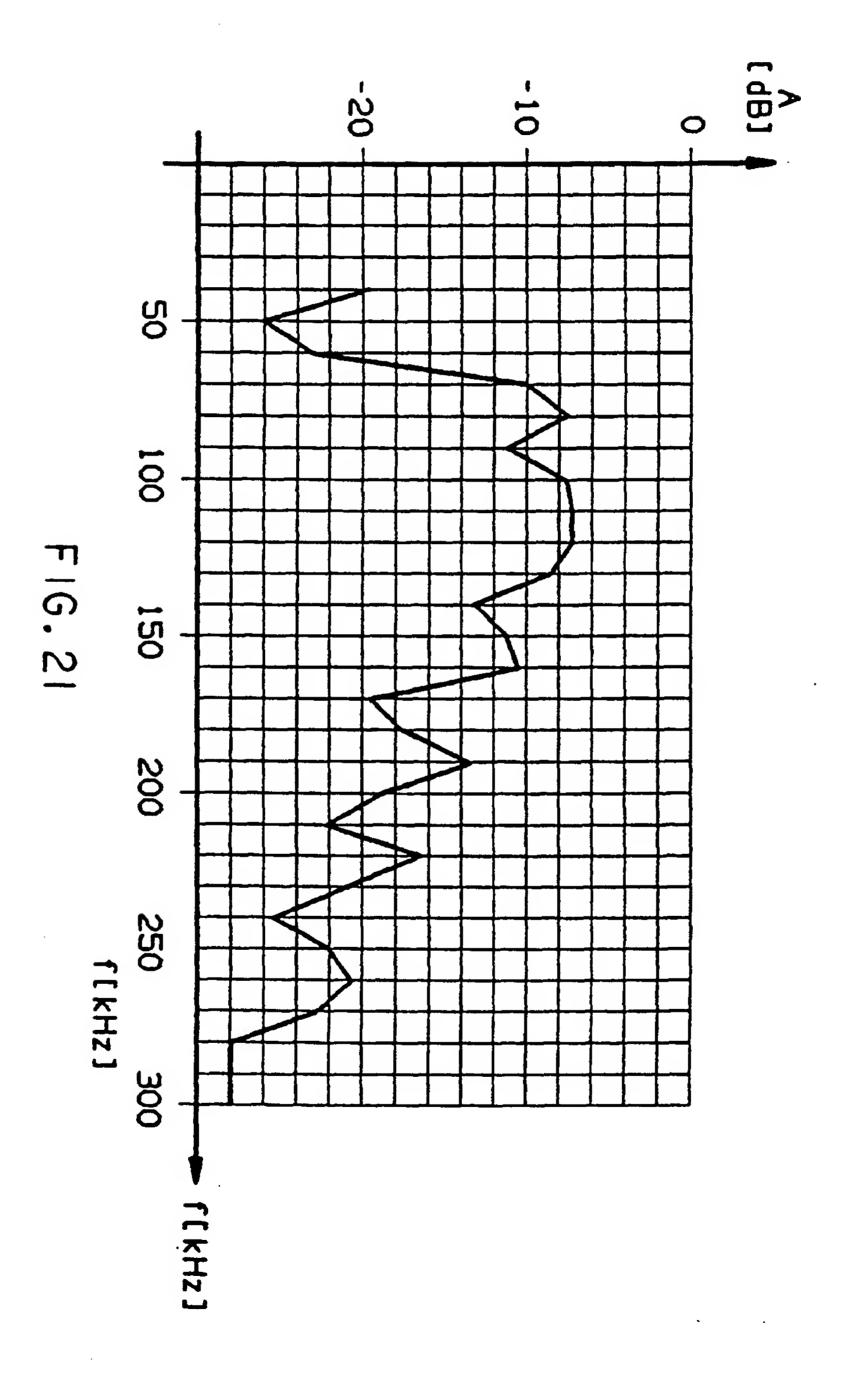


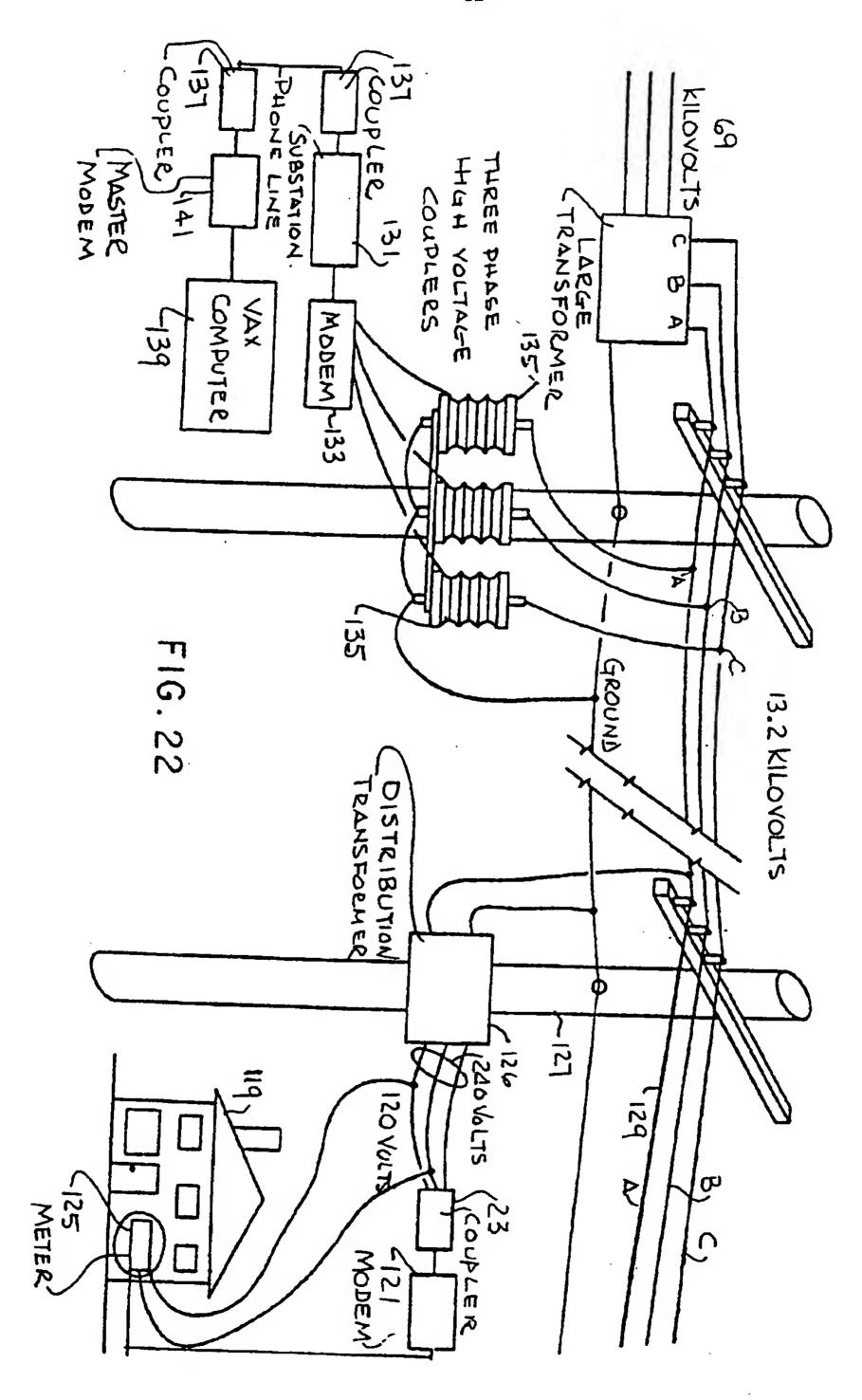


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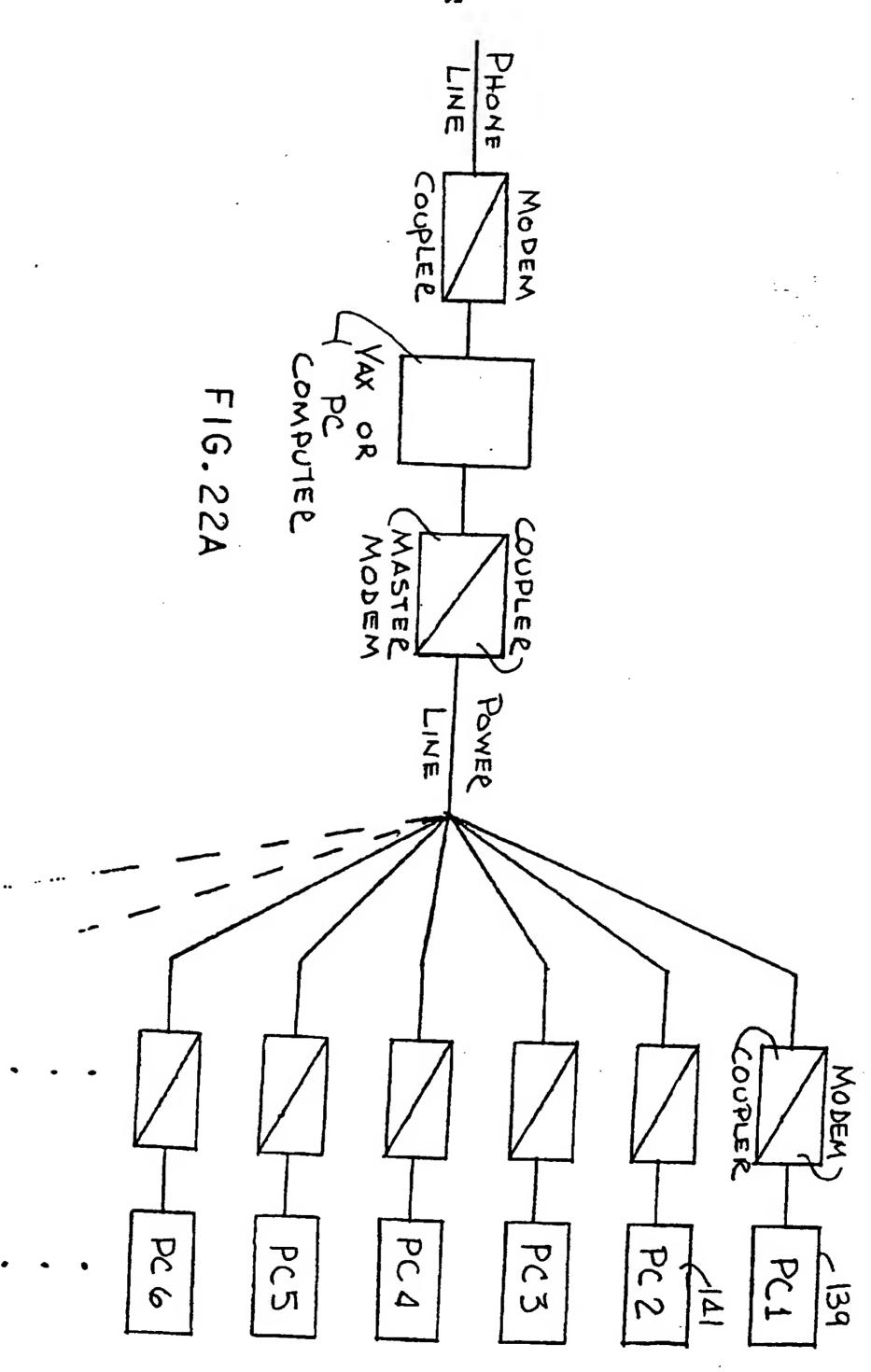


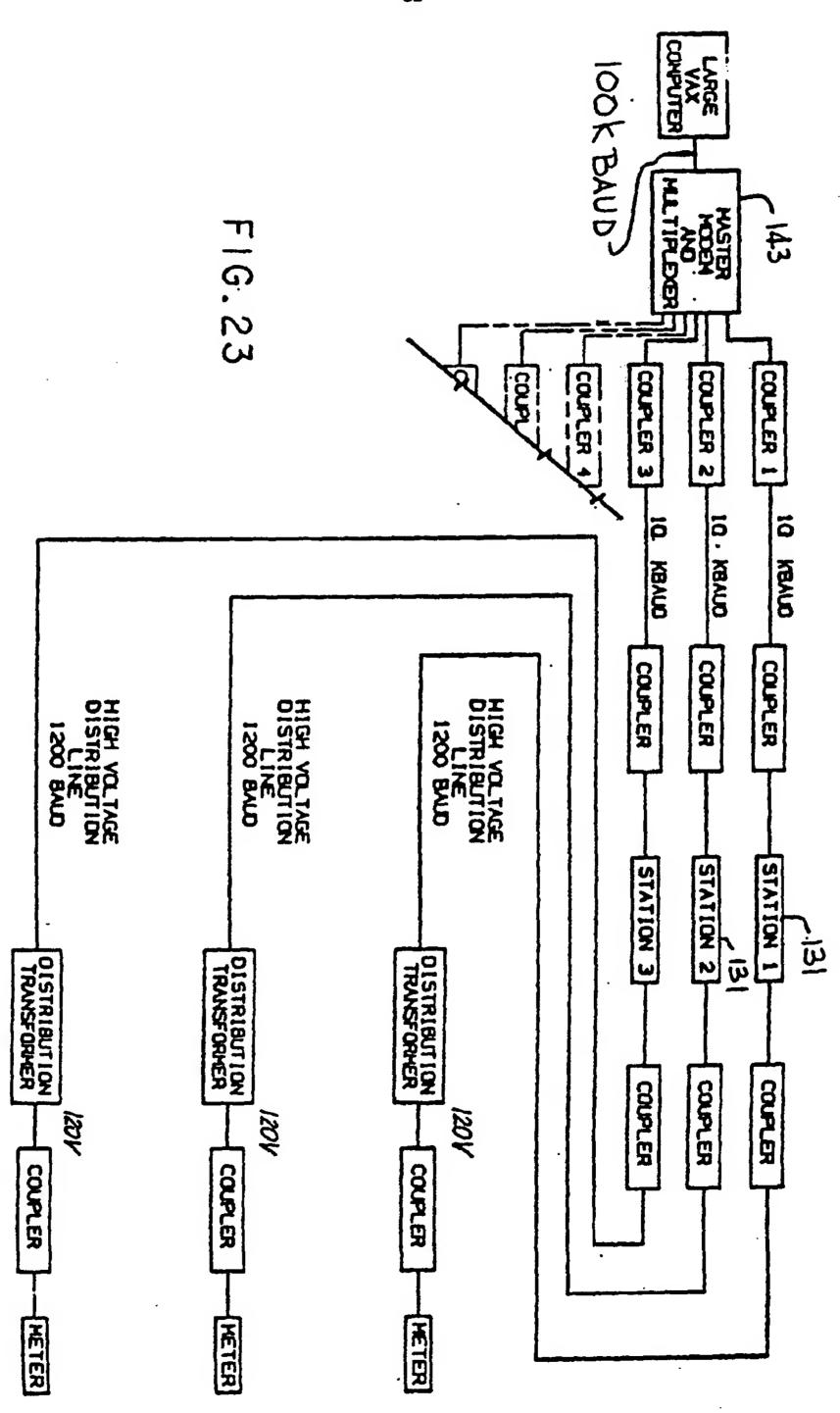
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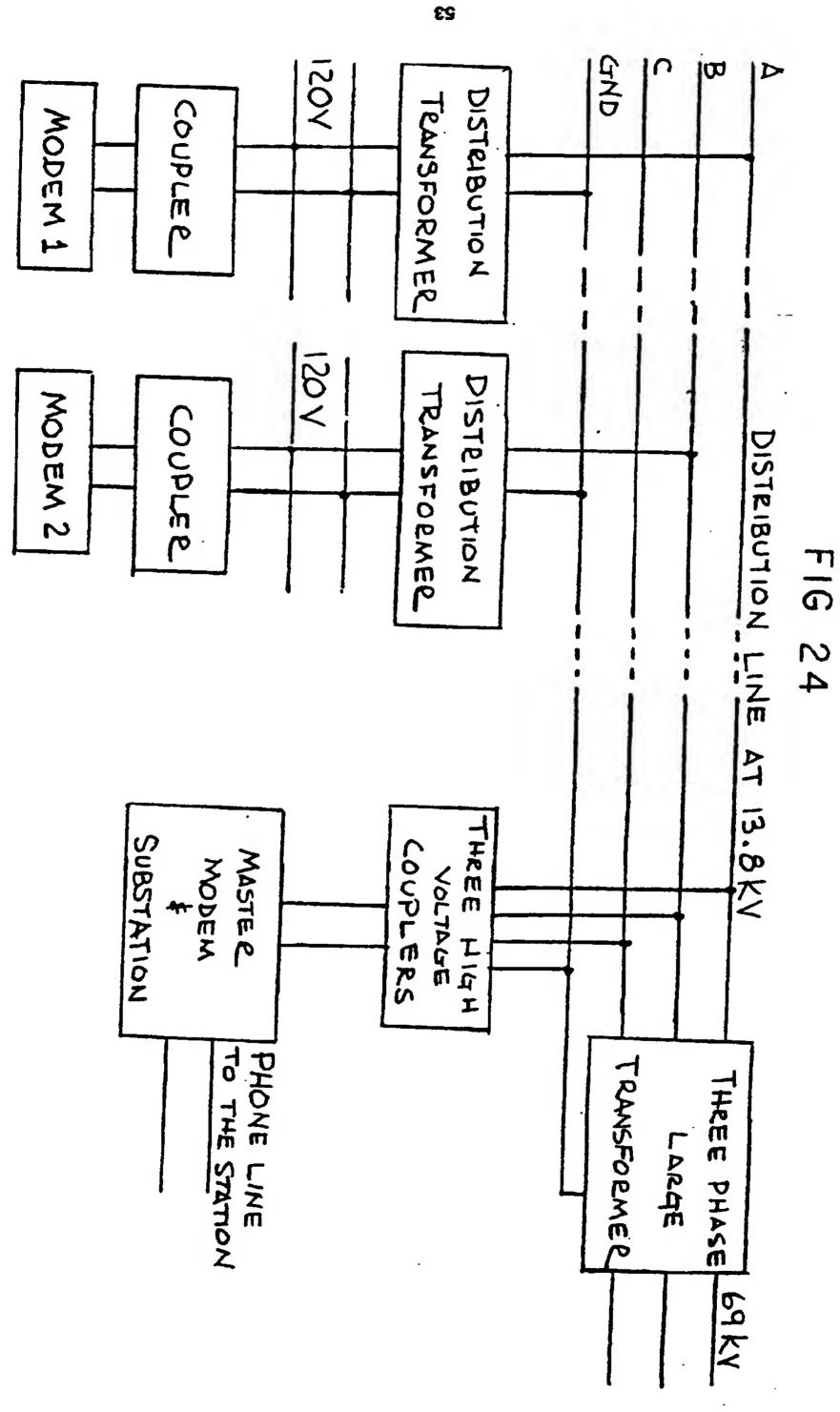


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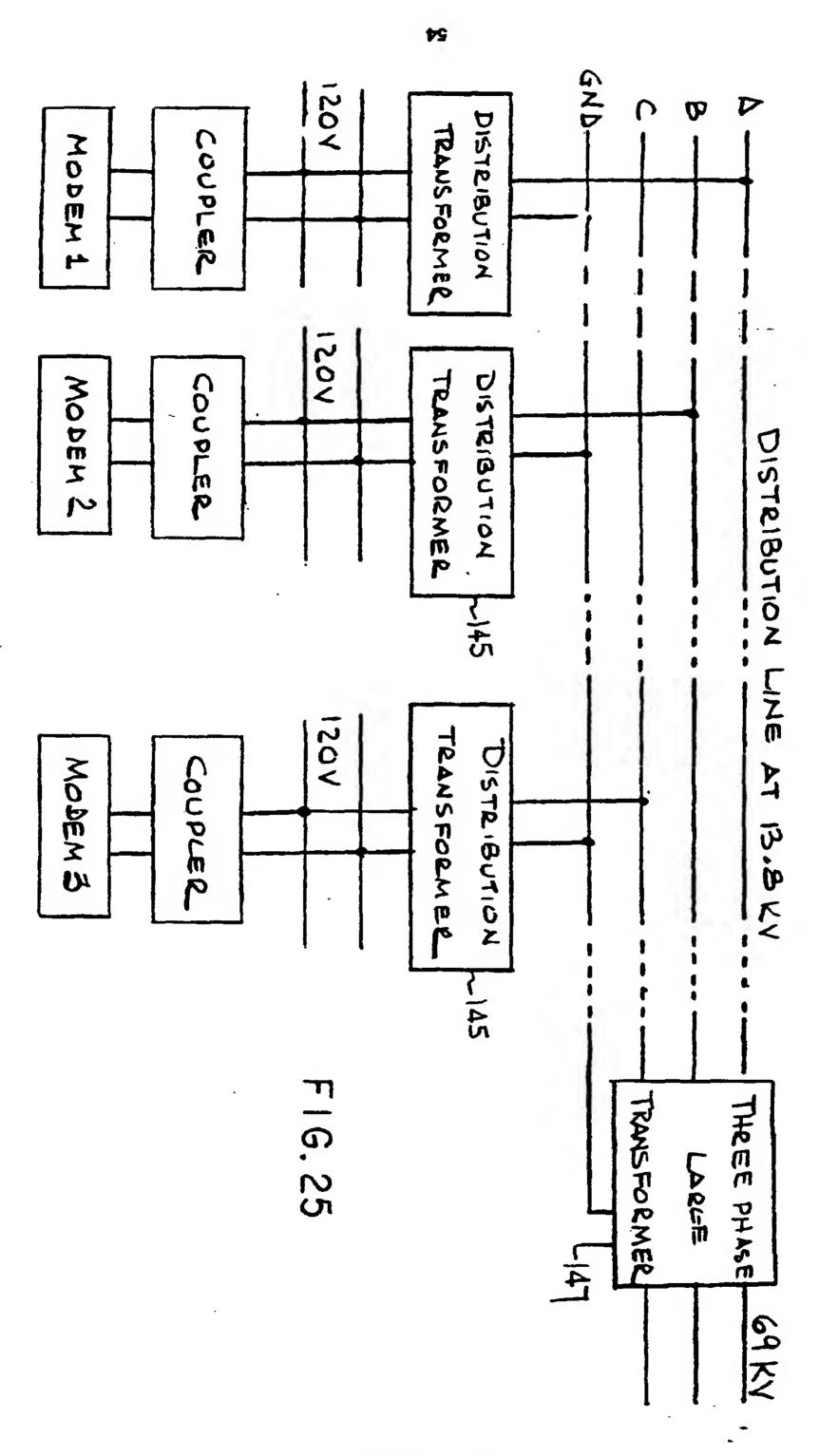




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